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PREFACE.

The general subject of boiler economy is too large to be treated fully and exhaustively in a pamphlet, and yet it is quite possible to compress a considerable number of useful suggestions into a fairly small space. That is what we have tried to do in the present publication, and we shall feel well repaid if the boiler owner finds that it throws a little light upon certain of his problems, and helps in some small measure to keep down his operating expenses. Further information upon any of the points that are covered, or upon any other topic relating to economy or safety in the operation of steam boilers, will be cheerfully furnished to our assured upon request.

The Travelers Indemnity Company employs a large force of expert inspectors, whose knowledge and experience are always at the command of our assured; and the services that these men render are worth far more than the cost of the insurance. Problems that require special study, and call for more time and consideration than any individual visiting inspector can devote to them, are laid before the staff of the Engineering and

Inspection Division of the Company, at its Home Office in Hartford, Connecticut. The best engineering skill in the country is thus made available, free of charge, to the owner of any boiler plant, large or small.

The facilities of the TRAVELERS' Engineering and Inspection Division are broad and complete in every respect. Engineers of national reputation are at its head, and under their direction expert services of every needful kind are rendered by well organized departments. in charge of competent men who are admitted authorities in their own special lines.

For patrons who contemplate putting in new boilers, or changing their present boiler plants in other ways, THE TRAVELERS is prepared to furnish practical specifications and plans, showing the most approved designs, and the best methods for executing the work in all its details.

THE TRAVELERS also maintains an efficient chemical department, including a well-equipped laboratory which is constantly and exclusively engaged in analyzing troublesome feed waters. Recommendations, based upon the conditions disclosed by these analyses, are returned to the boiler owners, who are thereby enabled to treat the water effectively and scientifically, so as to either avoid the formation of scale, or cause it to be deposited in a less objectionable form.

In a word, THE TRAVELERS is rendering to its patrons services that are unequalled elsewhere in any respect,—whether in the making of inspections, in the giving of valuable counsel tending to increase the efficiency of the plant, in the rendering of special services of every kind to meet the thousand-and-one unclassified emergencies and difficulties that arise, or in the prompt and generous payment of the losses that inevitably occur from time to time, despite the greatest care.

THE TRAVELERS INDEMNITY COMPANY,
Hartford, Connecticut.

Boiler Economy

1. **INTRODUCTORY:** In the following pages we have adhered as closely as practicable to the subject of boiler *economy*. The question of *safety* is comparatively distinct, and it is so large that it will be treated separately in a subsequent pamphlet of this series. We have nevertheless called attention, herein, to a few sources of danger, when these are related more or less intimately to the particular aspect of economy under consideration at the time, or when we have feared that the omission of a word or two of caution might be construed to imply that no serious danger exists.

The discussion of deterioration has also been deferred, in large measure, because this subject is related to safety more closely than to economy. Deterioration certainly has an economical phase, however, because it is a source of running or cumulative expense, which may be lessened or increased, within certain limits, by comparatively small variations in practice. We have therefore considered some few of its aspects.

We have touched upon boiler scale more fully than a strict interpretation of the title of this pamphlet would appear to promise. Some treatment of the scale question is certainly called for in connection with economy, and the rest of the discussion herein given is included because the problem to be solved is often complicated, and a more or less complete understanding of the whole subject may be essential to the intelligent treatment of a special case.

2. **SETTINGS AND GENERAL DESIGN:** In order to ensure a reasonable economy in the generation of steam, careful attention must be given, at the outset, to the general design of the whole boiler plant. The boilers themselves must be adapted to the work that is to be done, and to the fuel and water that are to be used. The setting, chimney, and all other parts, must also be intelligently designed and arranged, with a view to securing good combustion and as complete an absorption as possible of the heat that is generated by the fuel.

3. **TYPES OF BOILERS:** There are many kinds of boilers in use, but the commoner ones may be divided into two main classes, according to the location of the fire. They are called "externally fired" if the combustion of the fuel is effected entirely or mainly outside of the boiler; and they are called "internally fired" if the combustion occurs in such a way that the fuel-bed of the furnace is largely or completely enclosed

or surrounded by the boiler itself. (This is to be taken as a general description for purposes of explanation, rather than as an exact definition.)

Most boilers are composed of tubular parts, to a greater or lesser extent, and in such cases they are called "fire-tube boilers" if their tubes contain hot gases from the fire, and "water-tube boilers" if these tubes contain water, with the furnace gases circulating externally about them.

In Great Britain internally-fired boilers are used to a large extent, particularly in certain districts; while in the United States the preference is generally given to externally-fired boilers. In fact an internally-fired boiler is rather uncommon in stationary practice in this country, although locomotive and marine boilers with internal fires are met with everywhere.

In land practice in the United States, particularly in small plants, fire-tube boilers are more common than water-tube boilers,—largely because they are cheaper and easier to repair. Water-tube boilers are usually preferred, however, when the pressure is to be high, or when the load is so variable that ability to respond quickly to a sudden change in this respect becomes important. With proper design of the boilers, settings, and other appurtenances, there need be no material difference in efficiency among these various types. The type to be preferred usually depends upon the nature of the work, or upon that of the fuel or the feed water, or upon the available floor space, or upon the first cost, or upon the ease of cleaning and repairing, rather than upon any inherent and characteristic difference in efficiency.

4. **KINDS OF FUEL:** Coal is of course the chief form of fuel that is used in the generation of steam, though wood is still available in some sections, particularly in connection with saw mills. Oil and natural gas are used where they can be had at a cost that is not prohibitive, and the gases from blast furnaces are used to a considerable extent in the iron regions. Waste and refuse of many kinds are likewise burned with success for steam generation, though special furnaces are usually required, adapted to each particular kind of fuel. Coal being by far the commonest fuel, it will be assumed to be used, throughout the following pages, except where the contrary is expressly indicated.

In general, it is more economical to burn soft coal than hard, though this will vary somewhat with the locality, and also with the nature of the output of the plant. In some cases freedom from smoke is the determining factor, either because of local ordinances against smoke, or because smoke or some of the other volatile substances that are given off by soft coal would be detrimental to the product that is manufactured. In this latter case "economy" has to be construed in its broadest sense, as including the operation of the plant as a whole.

5. **BUYING COAL:** The best method of buying coal will vary with the quantity that is used. In small plants the cost of making frequent analyses and tests is usually prohibitive, and in such cases the buyer must be guided by general considerations, rather than by an accurate knowledge of the heating value of the fuel. He should see that the coal has been freshly mined, and that it comes from mines which yield a uniform and satisfactory product, as judged by his own experience or by that of others. It is better, in general, to be content with a supply of known and proved worth, rather than to experiment on any large scale with untried mines or sources. Experimenting in a small way may be encouraged, however, if the results are checked up by actual steaming tests, so that positive and reliable information is obtained, for future guidance. It is safest for the small buyer to deal with a merchant who has a good reputation to maintain, even though the first cost of the fuel is a little higher;—any small advance in price, under these conditions, being regarded as insurance against possible unfortunate experiences that might prove much more costly in the end.

In large plants, where the consumption of fuel is heavy, it pays to buy on what is called a "heat-unit basis", because in this way the consumer gets exactly what he pays for, in all cases. In applying this method, an estimate is first made of the number of pounds of water that will probably be evaporated by one pound of coal, under standard specified conditions, and a nominal or basic price is then agreed upon, as representing the value of the coal in case it should yield the exact amount of heat that has been assumed. Tests of the coal that is actually delivered are then made from time to time, and the basic price is corrected in conformity with the results that are obtained,—the dealer receiving a proportionately greater price if the heat production exceeds the estimated value, while the buyer receives a corresponding rebate if it falls short. In applying this method in practice, a sample shovelful is retained from each load of the coal, and all these samples are thrown into a suitable receptacle, where they are kept, protected from the air and the weather, until some definite and predetermined quantity has accumulated, or until one entire shipment of the coal has been delivered. The individual samples that have been saved out are then thoroughly mixed, and a smaller sample is withdrawn from the whole and sent to the chemist for testing.

6. **SIZE OF COAL:** In burning hard coal, the size should be carefully considered. Generally speaking, it is cheaper to use the finer grades, and in many plants "buckwheat" and "dust" coal are burned successfully and with good economical results. The main objections to the smaller sizes are that a much better draft is required to draw the air through the fuel-bed,

and that a larger fraction of the coal is likely to fall unconsumed through the grates into the ash-pit, and so be wasted. To burn the smallest sizes with success, the draft should be powerful, and the grates should be chosen only after consultation with an experienced engineer who is familiar with the problems that are involved. Experimenting with very fine coal, without experience or competent advice, is likely to be expensive.

7. **MOISTURE IN COAL:** Dealers commonly wet their coal before handling it, and the total amount of water absorbed may be quite considerable when the coal is fine or soft. Water is expensive when it has to be paid for at the same rate per ton as coal, and the buyer should therefore see that the coal is reasonably dry when it is weighed. If the coal is bought in quantities sufficient to warrant examination by an expert, the amount of water that it contains should be accurately ascertained and allowance should be made for it in determining the price to be paid. Water in the coal is expensive, not only because it must be paid for at coal rates, but also because it must be evaporated in the furnace; and to effect this evaporation an appreciable fraction of the total heat that is developed by the combustion must be absorbed and sent up the stack unused.

8. **STORING COAL:** Coal deteriorates to a sensible extent upon exposure to the weather, and supplies that are held in storage should therefore be covered by a shed or roof that will afford a proper protection. Coal that is closely confined is apt to grow hot, below the surface, and good ventilation of the bins is therefore desirable, so that the coal may be aerated and cooled as thoroughly as possible. The heating is doubtless due to the slow oxidation of impurities, and under some circumstances it may be rapid and intense enough to set the coal afire,—a phenomenon known as "spontaneous combustion". Fires sometimes originate in this way, deep down in a coal pile, and smoulder, unsuspected, for a long time. They are often very hard to extinguish. To guard against the indefinite spread of fires in the coal pile, whether they are of spontaneous origin or not, the storage place should be divided at frequent intervals into entirely separate pockets, by substantial walls of brick or other non-combustible material. This precaution is especially important when the coal is stored in large quantities, or when it comes from mines the output of which is known to be especially prone to self-ignition.

9. **HANDLING COAL:** The most economical way to handle the coal is to have it delivered from a track or roadway that is higher than the storage bins so that it can be dumped from the cars or wagons

directly into the bins. In accordance with this same principle the bins should also be arranged so that the coal that is needed for the boilers can be drawn off from their lowest points, and loaded upon cars, barrows, or specially designed conveyors, for transmission to the boilers. The bottom level of the bins should be a little above the boiler-room floor, if it is convenient to lay them out in this way, because the coal can then be delivered from the bins to the boilers on a slight down grade. Where hand-firing is practiced, it is best to run a small track from the bins to the firing floor in front of the boilers, and at such a distance from the fire doors that the coal can be thrown, easily and conveniently, from the cars directly into the furnaces. In larger plants, where mechanical stokers are used, it is desirable to store the coal at some height above the boilers, raising it to the storage place by conveyors, and delivering it to the stoker hoppers through chutes. (See, further, paragraph 43.)

10. **NATURE OF COMBUSTION:** The process of combustion consists in the active and rapid combination of the fuel with the oxygen of the air. If the coal were composed of pure carbon, and the combustion were perfect, the fuel would be entirely consumed, and would eventually pass up the chimney in the state of the invisible gas known as carbon dioxide (or, more familiarly perhaps, as CO_2 or "carbonic acid

gas"); but even in this ideal case the chimney gases would by no means consist of pure carbon dioxide, because air is not pure oxygen. Four-fifths of its bulk, approximately, consists of the practically inert gas nitrogen, and hence, even with perfect combustion and a pure carbon fuel, four-fifths of the gas passing up the chimney is nitrogen, and only one-fifth, at most, is carbon dioxide. The nitrogen takes no part in the combustion, except that by diluting the oxygen it checks the chemical action and causes it to proceed far more slowly than it would if the nitrogen were absent.

In practice the chimney gases contain various other substances besides nitrogen and carbon dioxide, because the fuel is never burned under strictly ideal conditions. If an excess of air is admitted to the furnace, a certain proportion of free and unused oxygen will pass up the chimney, while if the air supply is deficient the chimney will very likely discharge more or less of the gas that is known to the chemist as "carbon monoxide", and which burns with a pale blue lambent flame in household stoves when fresh coal has been recently thrown in. Moreover, coal is never pure carbon. In addition to a certain variable proportion of entirely incombustible matter which remains behind as ash, slate, and clinker, all coal contains more or less combustible matter besides the free carbon of which it mainly consists, and the softer bituminous varieties are particularly notable in this respect. The additional combustible substances to which we refer consist mainly of carbon and hydrogen, chemically combined with each other; and when they burn they generate more or less water-vapor, owing to the oxidation of the hydrogen. The natural moisture in the coal is evaporated at the same time, and the chimney discharges a considerable quantity of water-vapor from these two sources combined. The heat-producing power of coal varies considerably, according to the proportion of these secondary combustible substances that it contains, and numerous formulas and tables are available from which the quantity of heat that will be given out by a particular ton of coal can be fairly well calculated without an actual calorimetric test, provided we know the relative amounts of hydrogen, oxygen, and carbon that the coal contains.

The aim of the fireman should be to keep his fires bright, and to have the combustion go on so that carbon monoxide and smoke shall be kept down to a minimum, and so that carbon dioxide shall be present in the flue gases in a proper proportion. The only practicable way to accomplish this, in small plants, is by employing firemen who understand their business thoroughly, and who know by the appearance and behavior of a fire whether it is working properly or not. For larger plants, where a greater expenditure of time and money is permissible for securing economy, various forms of carbon dioxide meters have been devised for showing the percentage of this gas that is passing away through the flues. Some of them are good, and well worth using; but they must be handled by men of a higher grade than are ordinarily intrusted with the duties of the fire-room. Complete flue-gas analyses are also quite helpful in maintaining high efficiency of combustion, but these can be made only by men who have some knowledge of chemistry. In plants where large quantities of coal are burned, it will usually pay to keep a record of the percentage of carbon dioxide that is passing away through the flues. By varying the method of firing a little, and studying the effect of the changes upon this percentage, it is often possible to improve the fire-room practice in a considerable measure.

11. **SMOKE:** The black, opaque smoke that is often given off by the chimneys of boiler plants consists largely of myriads of little particles of unconsumed carbon, together with volatile and condensible tarry matters that are distilled from the coal by the heat, and which are passing away unburned. Cindery particles of coal or coke of tangible size may also be present in vast numbers. The production of black smoke is a sure sign of imperfect combustion, and the owners of plants that produce it in huge volumes should remember that such smoke is an expensive nuisance, and they should take strenuous measures to abolish it, in the

interest of their own pocketbooks. The light, grayish clouds that are often seen about the top of a chimney are of no especial significance as they consist mainly of condensed water-vapor. (See, also, paragraph 13.) Screens, ruled with graduated black lines, may be had for estimating the density of smoke, and the use of these screens often leads to a material improvement in the combustion.

Numerous special devices may be had for "burning" the smoke, or lessening its production; but although some of these are doubtless effective, it must nevertheless be admitted that none of them gives an ideal solution of the problem, because the cost of reducing the smoke by blowing air or steam into the furnace is likely to be fully as great as the saving that results from the consequent improvement in the combustion. The prevailing opinion among engineers is to the effect that "the best smoke consumer is a good fireman",—which means that by careful management under the guidance of an intelligent and skillful man, the combustion can be carried out well enough to avoid the production of black smoke in any considerable quantity. This is true only to a certain extent, however, for although the good fireman is without doubt a highly important element, the most essential feature of all is a properly designed furnace. (See paragraphs 12, 13, and 20.)

12. **DESIGN OF FURNACE:** Practice is exceedingly conservative with respect to the design of boiler furnaces for small plants. In larger installations, where the prospective coal consumption is much greater, it is common to consult a skilled and experienced designing engineer, to determine what is best, without regard to tradition; but in smaller ones the furnaces are still built according to the same conventional plan, year after year, with no especial effort to improve the general design in any way. We believe this to be a mistake, and we are glad to extend our services to small-plant owners who may wish to adopt the features that recent experience has shown to be conducive to greater economy.

To ensure good combustion it is of the first importance to keep the gases in the furnace as hot as possible, until the oxidation is entirely completed; but this fundamental condition is far from being realized in ordinary practice. In setting a horizontal tubular boiler, for example, it is usual to place one end of it immediately over the furnace, so that it is exposed to the direct action of the fire. In this way the gases, which are at a temperature of perhaps 2500° Fahrenheit as they rise from the fuel-bed, are covered, over the entire area of the furnace, by a metal roof or plate that has a temperature of perhaps 350°. In other words, the entire upper boundary of the furnace is maintained at a temperature some two thousand degrees lower than that of the furnace gases. The absorption of heat by this relatively cold surface chills the gases so that sensible portions of them are cooled below the temperature at which they are capable of uniting with oxygen; and if these cooled portions are not already completely oxidized, they are likely to escape up the chimney unconsumed, and a consequent waste of fuel is the result. The waste that is caused in this way can be minimized by properly proportioning the furnace, but it cannot be really eliminated so long as the attempt is made to burn the fuel under unscientific conditions.

Much better combustion can be had by erecting a so-called "ignition arch" over the fire, so as to entirely protect the gases from the chilling action of the boiler until the combustion is complete. To install such an arch properly, the boiler should be set at least a foot higher than is usual in ordinary practice, and the arch should be turned over the furnace from side to side, and be extended lengthwise of the boiler so as to cover the fuel-bed from the front end of the furnace back as far as the rear face of the bridge wall. There is no serious difficulty in making such an arch last well, if it is properly built in the first place, and if it rests securely against suitable buttresses at the sides of the furnace. It has no load to sustain, except its own weight. The arch should be built of special wedge-shaped fire-brick, made with a taper appropriate to the height and span that the arch is to have; and the brick should be laid with a thin paste of fire-clay, instead of with mortar or cement. The alternate courses of the brick should be set at slightly different levels, so as to make the under side of the arch irregular instead of smooth. The corners that are thus exposed become white-hot, and the ignition of any unburned portions of the gases that come from the fuel-bed is thereby greatly promoted. The arch should be high enough above the grates to allow the fireman to throw coal upon all parts of the fuel-bed without inconvenience, and to clean and bank his fires readily whenever it is necessary to do so.

The chief objection that boiler owners urge against installing an ignition arch of this nature is, that by doing so they sacrifice the heating surface that is immediately over the fire. The loss of a few square feet of heating surface in this way is far more than compensated, however, by the much better combustion that the ignition arch ensures. Moreover, the gases should be as hot as possible when they enter the tubes of a fire-tube boiler, because it is there that the absorption of heat should mainly take place.

The ignition arch, when properly put in, not only increases the economy of the plant by improving the combustion, but also obviates many of the troubles that arise in the boiler itself, under the usual conditions, from its direct exposure to the fierce heat of the fuel-bed. Bulging, burning, and cracks and leaks along the girth joints, are most apt to occur over the fire or the bridge wall. All troubles of this nature are diminished in large measure, and often eliminated altogether, by the use of an arch over the fire, as described above. It may be well to say that this device has long passed the experimental stage, and that it has been thoroughly tested by experience, and found to be excellent when properly designed and constructed. (See, also, paragraph 20.)

13. **DISTILLING THE COAL:** It is highly important, in burning soft coal, to avoid distilling off its volatile constituents so that they can pass out through the stack without burning. Some coal contains enough tarry or oily matter of this kind to give it an almost greasy character. Coal gas is produced by heating such coal in a closed space or retort, and by reflecting upon this fact some idea may be had of the cost of distilling the volatile portions of such coal wastefully in a boiler furnace. To avoid losses of this kind so far as possible, care should be taken to feed the coal into the furnace in small quantities, to keep the fire fairly bright at all times, and to see that sufficient air is introduced to permit the volatilized constituents to be properly consumed. When these volatile constituents escape unburned, they are usually accompanied by smoke; and the rich yellowish color that is often seen at the top of the chimney when burning bituminous coal is a sure indication of their presence in considerable amount. The yellow hue is often masked, however, by the dense black smoke that may

be given off at the same time. In a rough way it may be said that freedom from yellow or black smoke shows that no very large quantity of volatile matter is being distilled unburned; for while this test is not altogether accurate, it is good enough to be of material help to the fireman in bad cases.

14. **QUANTITY OF AIR:** To obtain ideal results, the total quantity of air admitted to the furnace, including that which passes up through the fuel and that which enters at the fire doors or through other openings, should be exactly adjusted to the needs of the fire. The admission of an excess of cold air is wasteful, because this excess serves no useful purpose, and yet it becomes heated in passing through the furnace. The heat that is required to raise this excess air up to the temperature that prevails in the uptake, where the gases leave the boiler to pass to the stack, is entirely wasted. This source of loss is real, and it should be remembered and considered; but as it is practically impossible to admit exactly the right amount of air to the furnace, and to admit it in precisely the right manner, it is exceedingly important to note that it is far better to admit *too much* air than *too little.* This is because the loss of heat by the distillation of unburned substances from the coal, and by the escape of the carbon monoxide gas that is usually present in large quantities when the air supply is deficient, is

far greater than any loss that is likely to arise from the admission of an excess of air, when the fireman is careful and intelligent. (See paragraph 20.)

15. **THICKNESS OF FIRES:** The fire under a boiler should be kept as thin as practicable, in order to avoid the formation of unnecessarily large quantities of carbon monoxide gas. There is no loss from the production of this gas, if it is all burned again in the furnace; but when it is generated in great amounts, the escape of some sensible portion of it in the unconsumed form can hardly be avoided. Many persons believe that carbon monoxide is formed only when the fire is black on the top, from the addition of fresh coal. This is an error. The production of the monoxide is due mainly to excessive thickness of the bed of fuel on the grates, or to deficiency in the air supply; and it may be generated in large volumes from either of these causes, even when the fire is quite bright. So far as concerns loss by the wasteful production of carbon monoxide (as distinguished from the loss by direct distillation, noted above in paragraph 13), the blackness of the fire on the top is objectionable mainly because there is then far more likelihood that the monoxide, when formed, will escape unburned. The air entering through the ash-pit combines with the coal in the lower layers of the fire and forms carbon dioxide, which escapes unchanged

if the draft is good and the fuel-bed is not too thick. If there is an excessive thickness of fuel, however, or if the draft is poor so that the gases require too long a time to pass through the fire, a further chemical action occurs, the carbon dioxide taking up more carbon from the heated coal in the higher layers of the fire, and becoming thereby transformed into the monoxide,—two volumes of the monoxide being formed, in this way, for each volume of the original dioxide. When the fires are at all thick, especial care should be taken to admit more air, so that the monoxide that is formed may have plenty of oxygen mingled with it to enable it to burn properly. As a rule, the fire should not be more than eight or nine inches thick when burning hard coal, but with soft coal the fuel-bed must be somewhat thicker. The fire should be thicker at the back end of the grate than at the front, because air draws up through the fuel more freely at the back end, if the thickness of the fire is everywhere the same. This condition is usually met by slightly inclining the grates, and keeping the upper surface of the fuel-bed level. (See, also, paragraph 29.)

16. **FREQUENT FIRING:** It is far better to throw on a little coal at a time, and keep the fires bright, than to fire more heavily and at longer intervals. The loss from the distillation of unconsumed oily and tarry matters can be kept down in this way. because

when fresh coal is scattered lightly over a bright fire the gases that are given off by each particle of coal become immediately ignited, if there is sufficient air present to burn them. The ideal method of firing would be to keep sprinkling small quantities of fresh coal upon the flame bed continuously, at a rate adapted to the rate of combustion that is to be maintained. This cannot be accomplished satisfactorily by hand-firing, but it may be approximated by firing frequently, using small amounts of coal, and seeing that what is thrown on is well distributed. The fireman should be careful not to carry out this idea too literally, however, because in so doing he might have the furnace doors open nearly half the time, and this would be bad practice, as explained below in paragraph 20. He should bear in mind the *principle* that the suggestion of frequent firing involves, and should endeavor to put it into practice as well as he can, consistently with preventing the inflow of an unreasonable amount of air through the furnace doors.

17. **HOLES IN FIRES:** It is highly important, in running a boiler fire, to avoid holes in the fuel-bed. It is somewhat difficult to do this when the fire is thin, but an experienced man will be watching for the holes and will stop them as often as they are found. A "hole" in a fire is a place where the grate has become uncovered, or nearly so, by the burning away of the fuel, or from

any other cause. Such holes have two detrimental effects. They allow large excesses of cold air to pass through the uncovered parts of the grate, thereby chilling the furnace gases and lessening the efficiency with which the heat is absorbed from them by the boilers, and their presence also cuts down the supply of air through other parts of the fire at the same time.

18. **ALTERNATE FIRING:** Many firemen favor the plan known as "alternate firing", which consists in throwing coal into one side of the furnace at a time, leaving the fuel-bed upon the other side uncovered and at a white heat. The advocates of alternate firing claim that it ensures the ignition of any carbon monoxide that may be formed, and of the volatile substances that are distilled off from the freshly-fired side, so that each will be burned in the proper manner. Firing by this method may be better than feeding large quantities of fuel to all parts of the furnace at once, and it may yield good general results at the hands of a man skilled in its use. Nevertheless, careful experiments carried out in recent years by the United States Bureau of Mines, under the direction of Mr. D. T. Randall, indicate that alternate firing is measurably inferior, on the whole, to the method of sprinkling the coal lightly, and as uniformly as possible, over the entire grate at one time.

19. **COKE FIRING:** This is one of the best methods of firing soft coal by hand. It is known also as "bank firing", and consists in banking up a windrow of fresh coal across the front edge of the fire near the furnace doors, while leaving the coal on the rest of the fuel-bed at a white heat. The volatile parts of the fresh coal are distilled off by the heat, and in passing over the white-hot fuel-bed they will usually be completely burned, if there is a sufficient amount of air present in the furnace to combine with them. After the volatile parts of the fresh coal have been distilled off, so that what remains is coked and thus transformed into practically pure carbon, the windrow is pushed back over the grates so as to cover them with a uniform layer. This is a very ancient method of firing.

20. **ADMISSION OF AIR:** To guard against the escape, unburned, of carbon monoxide gas, and of the tarry matters that are distilled off from the coal, it is desirable to admit an extra supply of air just after fresh coal has been thrown into the furnace, and also when the fires are thicker than usual. For this purpose the fire doors are usually provided with draft registers, and these should be well regulated at all times. The amount of air that enters the furnace in this way is not sufficient to take care of any considerable quantity of freshly-fired coal, however, and it is therefore desirable to keep the fire doors themselves open by a small

amount while the first part of the fresh coal is burning off, unless the furnace is designed so that the requisite air can be introduced in some better way. It is usually sufficient to "crack" the doors, as the firemen call it,—that is, to leave them open by a crack. Care should be taken to avoid the admission of too great a quantity of air in this way. When the fire doors are left open to any great extent and for any considerable time, there is danger of the boiler becoming locally chilled sufficiently to start cracks or checks in it, this action being especially notable along the first girth joint of a horizontal tubular boiler, back of the fire door. Having these facts in mind, the fireman should be careful not to "crack" the doors too far, nor to leave them wide open any longer than may be necessary, when he is firing.

It is not scientifically correct to admit cold air through the fire doors, but they are very generally used for this purpose, because in most of the boiler plants of the United States no other means of admission is provided. It would be best for the air to enter the furnace through the fuel-bed, under all circumstances; but as there are times when a sufficient amount cannot be had in this way, it is necessary to consider what mode of admission is most advisable for the supplementary supply. Of the various methods that have been tried or proposed, admission at the bridge wall is by far the best, when the setting is properly designed with this in view. The bridge wall should be hollow, with a space, about half as wide as the length of a fire-brick, running through it from one side of the furnace to the other. Fire-bricks should be laid over this space to form the top of the bridge wall, the bricks being set on edge, with their lengths parallel to the length of the furnace; a clear interval about one-quarter of an inch wide being left between each brick and its neighbors, for the exit of the air. Ducts through the brickwork of the setting convey the air to the bridge wall, and dampers are placed in these ducts so that the supply can be regulated at will. Cleaning doors are also provided, for removing the fine dust that accumulates in the air passages. Air admitted in this way cannot chill the boiler, and it is much more effective in promoting combustion than it would be if admitted through the fire doors.

21. **DAMPERS:** The damper in the flue leading to the chimney or stack is intended for regulating the fire, and thereby controlling the steam pressure also. It is much better to check the draft by closing the damper partly or wholly, rather than by opening the fire doors so as to admit cold air into the furnace. The damper should be nearly closed when firing or cleaning fires, to prevent chilling the boiler by the large quantity of cold air that would otherwise be drawn into the furnace. Just enough draft should be left on, at these times, to prevent flames or hot

gases from rushing out through the fire doors when they are opened. Automatic regulators are now common, for closing the dampers when the steam pressure exceeds some predetermined value. They are actuated by the pressure of the steam against a piston or a flexible metallic diaphragm. In heating residences by steam, automatic damper regulators (usually of the diaphragm type in this case) are almost a necessity; because if they were not employed it would be necessary to have an attendant near by during the entire day.

22. **DRAFT:** A good draft is one of the most essential things about a boiler plant, and special attention should therefore be paid to it when the plant is laid out. It is easy to cut the draft down if it is too strong, but if it is too feeble the owner of the boiler is faced by a serious situation. The value of a powerful draft is particularly appreciated when some emergency makes it necessary to force the boilers beyond their normal capacity for a time. A strong draft also makes it feasible to burn relatively cheap and low grade fuels.

23. **CHIMNEYS AND STACKS:** Chimneys and stacks should have a capacity considerably in excess of the normal needs of the plant, in order to provide for temporary overloads and for future increases in the

number of boilers. Brick or sheet steel may be used in their construction, the choice being governed mainly by the relative cost of construction and maintenance, and often by location and architectural considerations. Brick chimneys, when properly designed and constructed, are quite permanent and need but little repairing. They should have an inner lining, entirely separate from the outer portion, and preferably extending to the very top or nearly so. This lining is made thinner than the outer wall, because it does not have to resist wind pressure. It serves to protect the outer wall from the heat, thus preventing the formation of cracks from uneven expansion and from the chilling action of rain. The lining should be made of fire-brick, to its entire height; and it should preferably be laid up with fire-clay. Brick chimneys, like brick settings, often leak air sufficiently to damage the draft to an appreciable extent. (Compare what is said concerning leaky settings, in paragraph 24.) The same possibility should be considered in connection with steel stacks also, and their joints should be calked at all points, in order to keep the leakage down as much as practicable. This precaution is often neglected, and the efficiency of the stack is correspondingly reduced. Leaks in or around the smoke flue should be promptly detected and stopped, and special attention should be given to the points at which this flue enters the chimney or stack. Steel stacks should be painted from time to time, to protect them from the weather and from the corrosive action of the hot gases from the furnaces. Steel stacks are often made without any lining of brick, but such a lining is to be strongly recommended, because it tends to prevent corrosion of the stack on the inside, and it also reduces the radiation from the stack and in this manner improves the draft.

24. LEAKAGE THROUGH BRICK-WORK: Care should be taken to keep the joints of all the brick-work about the boiler tight, so that air cannot leak in through any part of the setting, and mingle with the products of combustion. Leakage of this kind chills the furnace gases so that the heat is not absorbed from them with the same readiness, and it also injures the draft. The action of the air that leaks in through the setting is similar, in these respects, to that of the air that enters through the fire doors when they are left open too far. It is not necessary that the openings admitting the air through the setting should be individually large, in order to experience undesirable effects, for the multitude of small chinks that exist in a loosely-built brick wall can unitedly pass a very considerable quantity of air. Leakage directly through the brick-work of boiler settings is much more common than might be supposed, and in many cases there is a serious loss of economy from this cause, which is not detected because its existence is not realized. These considerations show the importance of keeping the brick-work of the setting in good repair at all times.

25. MECHANICAL DRAFT: This term covers every method of obtaining draft which requires the expenditure of power or steam, either by running fans, or by the operation of jets of steam or air. When the air required for combustion is delivered into the ash-pit under pressure (the ash-pit being then closed), the draft is called "forced"; and when there is an exhaust fan connected to the uptakes of the boilers, so that the pressure in the furnace is less than that of the atmosphere, the draft is said to be "induced". The merits of mechanical draft, as compared with the "natural draft" that is obtained by a chimney, vary greatly with the attendant circumstances. Fans are preferable to steam jets unless the fuel is exceedingly cheap, because the fans can be operated by expending from one to five per cent. of the total quantity of steam that is formed, while the steam jets usually require from ten to twenty-five per cent. of it. A plant fitted with mechanical draft needs no tall chimney, and a greater fraction of the heat of the furnace gases can be absorbed and utilized, because the draft does not depend upon the escaping gases having a certain temperature, as it does when using a chimney. On the other hand there is a constant operating expense for the fans, and an uncertain but real cost for repairs and general upkeep, Any leakage that there may be, through the setting or its fittings, will be outward when forced draft is used, and for this reason the fire-room is likely to be hot and full of objectionable odors if the setting is not tight at all points. Moreover, when working with forced draft it is important to shut off the air supply before opening the fire doors, because otherwise the fireman is quite likely to be burned by the outward rush of the furnace gases, and if this precaution is forgotten or neglected, accidents are likely to result. (In marine practice this source of danger is removed by keeping the boiler room tightly sealed, and discharging the air into the room itself: but the closed-room plan is hardly feasible in land practice.) When induced draft is used, there are difficulties in the way of lubrication to consider, and the likelihood of corrosion from the hot gases has also to be taken into account. These can be overcome by proper design and construction, but if the plant is not installed intelligently they are almost certain to give trouble. Whether the mechanical draft be forced or induced, some provision must be made for starting the plant when the boilers have all been out of service for a time, because the draft is very light indeed until a sufficient amount of power is available for operating the fans. Mechanical draft has many advantages in addition to those already mentioned. Economizers and superheaters can be placed in the boiler flue without fear of disturbing the draft, provided the passageways for the gases are ample in size; heavy temporary loads, such as are encountered in electric lighting and street railway work, can be met quite promptly; lower-grade fuels can be used, because the fans can be designed and operated so as to give any draft within wide limits; and the speed of the draft fans can be regulated automatically by the steam pressure, if it is so desired. Yet notwithstanding all these points in favor of mechanical draft it should not be adopted without first taking advice from some disinterested expert who is familiar with all the conditions that must be met.

26. RECENT THEORIES OF DRAFT: It is conventionally taught that the best absorption of heat can be had in a horizontal tubular boiler (or any other boiler of the fire-tube type), when the furnace gases pass through the tubes slowly, so that there may be plenty of time for the heat to leave them and enter the boiler. This has been questioned by eminent experts, who maintain that better results can be had by causing the gases to flow through the tubes with a much higher velocity. This view is based partly upon experiment and partly upon the hypothesis that the stream of gas flows through the tube without much internal agitation when the speed is low, so that the same particles of gas may remain in contact with the metal during the entire time of transit. In consequence, the inner surface of the tube is supposed to be lined throughout with a layer of gas that has given up most of its available heat soon after entering the tube, and which is therefore relatively cool; while the central portion of the gas stream, being but little disturbed, does not come into contact with the tube, and hence does not give up its heat properly. The advocates of higher velocities claim that when the gas travels at a greater speed, the irregularities of the surface of the tube cause the stream to become turbulent, so that its parts mix far better, and the absorption of heat is thereby greatly facilitated. Engineers are not entirely agreed with respect to the merits of this question, but there is a large amount of experimental evidence in favor of the higher gas velocities, and it is probable that the influence of the newer views will soon be felt quite markedly in the design of commercial fire-tube boilers.

27. **GAS AND OIL FUEL:** Crude petroleum, or fuel-oil that is obtained from it by first distilling off the lighter constituents such as gasoline and kerosene, is a valuable and convenient form of fuel, and it would doubtless be far more widely used if it were cheaper and more abundant. The entire production of petroleum in the United States would not be sufficient to supply our railroads alone, and it is manifestly impossible, therefore, for oil to replace coal on the grand scale. When oil is used, it is forced into the furnace in the form of spray, impelled by a jet of steam

or compressed air. The burning spray should not be allowed to strike directly against the boiler, because the heat is very intense and is likely to produce overheating and burning of the metal, especially if the boiler contains scale or grease. The spray should be made to impinge against a mass of fire-bricks, piled openly or loosely in the furnace with considerable spaces between them, and arranged somewhat like alternate squares on a checker-board. The labor required in running boilers with oil fuel is much less than that involved in operating with coal, and this saving has an important bearing in considering the relative merits of the two. There is no hauling or shoveling to be done when using oil, and there are no ashes to remove. (Some kinds of oil leave a residue, but it is usually comparatively small in quantity.) In burning oil the combustion can be nicely regulated and made almost perfect, the temperature in the furnace can be kept practically constant, and the system is flexible in every way, inasmuch as the fuel supply can be immediately cut down or greatly increased, to take care of all emergencies. Gas (whether it be natural gas, or manufactured fuel-gas, or waste gas from some process that is being carried out in the plant) can be used with the same readiness as oil, but neither gas nor oil should be installed except under the advice of a competent engineer who is familiar with the proper methods of burning these fuels, and who is also well informed as to their dangers. The chief dangers in either case are those of fire and explosion, and in most cities it would be impossible to store a quantity of oil sufficient to provide for the wants of the plant for a reasonable length of time, without violating some ordinance or fire regulation. When burning either gas or oil, there is always more or less danger of explosion in the furnace, or in the gas passages, unless the fireman is a specially careful man. In lighting the fire, burning cotton waste or a burning torch of some other kind should be placed in the furnace before the fuel is turned on, so that the flame may be started at once and before there has been any opportunity for explosive vapors to collect in the furnace or in pockets about the setting. If a burner should snap out, the oil or gas supply should be turned off at once, and the furnace and all the gas passages should be thoroughly ventilated before again lighting the fire. The same precaution of ventilation should likewise be taken at all times,—and especially after the boilers have been lying idle,—before men are permitted to enter any of the furnaces or gas passages, or to introduce open lights into them; because there is always more or less danger of leakage of the oil or gas, and of the consequent accumulation of suffocating or explosive vapor-mixtures or gas-mixtures, in the spaces and passages of the settings. Failure to exercise proper care in this respect may bring serious consequences.

28. **BURNING WASTE:** Waste of the most unpromising character can often be burned with success and utilized in the generation of steam, but special forms of furnace are usually necessary in order to carry out the operation properly. Shavings, sawdust, bagasse, and spent tanbark are among the commoner forms of waste that are put to use in this way, and many cities are also generating steam by utilizing their refuse as fuel. The most important thing to do in burning waste, especially when it is damp or wet, is to handle the fire so that an abundant supply of air shall always be present, and a large surface exposed, over which the combustion can extend, and from which the water that the fuel contains can be evaporated. It is of prime importance, in handling wet material, to see that it becomes dried at least as fast as it is consumed; for if this condition is not fulfilled the dry part will burn up and the fire will then go out. In starting a fire that is to burn waste, it is usually necessary to run with some other kind of fuel until the furnace has become thoroughly heated. The waste can then be added a little at a time, until the mass has become well ignited and a considerable part of it has become dry. Furnaces for burning waste are preferably detached from the boiler itself, the combustion taking place in front of the boiler, or below it, in a separate furnace from which the heated gases are led to the boiler by means of suitable fire-brick passageways. By conducting the operation in this

way, it is possible to feed the fuel through openings in the top of the furnace,—which is far better than introducing it through doors in the front of the setting, as in firing with coal. The fuel should be thoroughly stirred up and worked over as it dries out and burns upon the grates, so that fresh portions of it may be continually brought to the surface. It is often best to handle the waste by a conveyor of some kind, the form of which will naturally depend upon the nature of the material itself. Blowers are used with good effect for handling shavings and dry sawdust. Considerable skill is required in order to burn wet waste effectively, and men cannot be expected to obtain first-class results until they have had the necessary training and experience.

29. **GRATES:** In starting a fire in the morning, or at any time after a boiler has been shut down, it is a good plan to sprinkle a layer of coal over the grates before the shavings and wood are placed upon them. This tends to preserve the grate bars. When the boiler is in operation, the ash-pit doors should not be kept closed for any considerable time, because if they are, the grate bars are likely to become overheated, and to either burn or warp. The air that is continually drawn through them in the normal operation of the boiler tends to keep them cool enough to prevent such burning or warping. The grate area must be properly

proportioned to the boiler if the best results are to be obtained, and the spaces between the grate bars should also be adapted to the draft and to the kind of fuel. It is evident, for example, that there will be a large waste if unnecessarily wide spaces are used when burning small sizes of coal, and it is equally evident that the openings must be wide enough to admit the quantity of air required for combustion under all circumstances. Generally speaking the area of the grate should be determined properly, before the setting is built; but when the original proportions are faulty, a marked improvement can frequently be made, by some entirely practicable change, even after the boiler has been erected and placed in service. Grates are often unnecessarily large, and in such cases a decided improvement in the performance of the furnace can be brought about by partly covering them over, or by altering the shape of the bars. A low-grade fuel usually requires a larger grate than is necessary for a fuel of a better grade. If the bars are of the fixed type, it is customary to lower them about three inches at the back end, where the fire is apt to burn out quickest. (This feature has already been considered, in paragraph 15.) Grates are often constructed so that their bars can be shaken by means of a lever, for the purpose of sifting the fine ash down through the fire, and breaking up the adherent clinkers. These are called "shaking grates", and if the bars can be turned far enough to dump the fire into the ash-pit, they are called "dumping grates". Shaking grates and dumping grates work well with some kinds of fuel, and poorly with other kinds. The dumping kinds must be used intelligently, or there will be a considerable and unnecessary loss of fuel in cleaning the fires with them. One of the main advantages claimed for all these mechanically operated grates is that when they are used with a fuel to which they are adapted, they tend to improve the economy of the boiler, and to prolong its life, by doing away with the necessity of opening the furnace doors when cleaning the fires, and thereby admitting large volumes of cold air. Many special forms of grates are used, particularly in connection with mechanical stokers. (Paragraph 43.)

30. **COMBUSTION CHAMBER:** The space back of the bridge wall in the ordinary horizontal tubular boiler, and any space that may be equivalent to it in boilers of other types, is known as the "combustion chamber". The gases from the fuel-bed, and any supplementary air that may have been admitted at the fire doors or elsewhere, should have become thoroughly mixed by the time they have passed the bridge wall; but the chemical combinations that begin at the fuel-bed are still incomplete, as a rule. The combustion chamber is in effect a local enlargement of the general channel followed by the hot gases, and it serves to temporarily check their velocity and afford time for

the completion of the oxidation. To accomplish this end properly, the combustion chamber should be ample in size, and it should be kept well cleaned out. Otherwise the fine particles of coal and ash that lodge in it will collect until the entire space becomes nearly choked up. A combustion chamber thus neglected fails to fulfill its mission, because it does not prevent the gases from passing swiftly onward to the tubes, and becomingt hereby chilled, by intimate contact with the relatively cool surfaces of the boiler, so that further combination does not occur.

31. **TUBES:** The size number, and location of the tubes in a boiler depend not only upon the type of the boiler but also upon many other circumstances. In water-tube boilers the tubes are usually four inches in diameter externally, and their number and arrangement depend upon the particular type of the boiler and upon its rated capacity. In a fire-tube boiler, such as the horizontal tubular, the size and number of the tubes should vary with the character of the water and the fuel that are to be used, as well as with the size of the boiler, and lack of judgment in dealing with these points may have a marked influence upon the efficiency that is realized. Designers and builders of horizontal tubular boilers sometimes make the mistake of putting in too many tubes. When the number is too great, some of them may be practically useless for the purpose of absorbing

heat, and in this case their introduction involves expense without any corresponding benefit. Extra tubes may be distinctly detrimental, in fact, by occupying space that could be filled with water to better advantage.

32. **BAFFLE PLATES:** In most forms of water-tube boilers, baffle plates are placed among the tubes at different points, to regulate the flow of the furnace gases and direct them so as to secure the greatest possible amount of heat absorption. These baffle plates undoubtedly add to the efficiency of the boiler when they are correctly placed, and it is therefore important, each time the boiler is cooled down sufficiently for a man to examine them, to see that they have not become displaced. Some of the tiles of which they consist may have fallen out or become broken, or the baffles may become otherwise displaced, as a whole or in part. In any case of displacement a passageway is likely to be opened for the flue gases, which will be shorter and easier than the one they are supposed to follow, so that a considerable fraction of the gases from the furnace will pass to the chimney or stack by a short cut, and without giving up as much of their heat as they are supposed to yield when the baffling is in good order; and of course this means a loss of efficiency.

33. **SMOKE FLUE:** The size and shape of the smoke flue that conveys the waste gases from the boiler

to the chimney or stack have an important influence upon the capacity of the boiler and upon its efficiency. If the flue receives the waste gases from one boiler only, its least sectional area should bear a proper relation to the grate area of that boiler; and if it receives the waste gases from several boilers, its cross-sectional area should be larger than would be necessary for a single boiler, in proportion to the number of boilers that are to be served. The smoke flue should lead to the chimney or stack as directly as possible. If the course of the flue cannot be straight, sharp angles should be carefully avoided, and the corners should be turned by forming the flue into curves of large radius, so that the gases may pass around them with very little friction and with no violent change in direction.

34. ECONOMIZERS AND SUPERHEATERS: When economizers or superheaters are placed in the flue leading from the boilers to the chimney or stack, care must be taken to see that the passages through these devices are large enough so that their combined area of cross-section is at least as great as that of the flue itself in other places. The draft will be seriously affected if this condition is not fulfilled, and it may be difficult or impossible to run the boilers properly. It must also be remembered that economizers and superheaters remove heat from the flue gases,—this being the very purpose of their existence. The flue gases being thereby cooled to some considerable extent, the draft of the chimney is correspondingly reduced. Hence it may not be wise to install an economizer or a superheater where the draft is already poor, without making other changes in the plant that may be more or less expensive. The installation of such devices should not be undertaken, in fact, without consulting some expert. THE TRAVELERS INDEMNITY COMPANY is glad to give advice to its patrons on these points, or upon any others relating to the boiler plant. (See paragraphs 90 and 91.)

35. **SOOT:** All tubes, passages, and surfaces about the boiler should be kept free from soot, because this is an exceedingly poor conductor of heat, and if it is allowed to accumulate in quantity it will cut down the efficiency of the boiler to a serious extent by diminishing the absorption of heat. The various tubes, passages, and surfaces should be cleaned as often as may be necessary in order to avoid such accumulation, and the man in charge of the plant can best tell, from experience, at what intervals this must be done. It is not at all uncommon for water-tube boilers, in particular, to be neglected until the soot in some of the passageways accumulates to an almost incredible extent. The existence of large quantities of soot indicates that the combustion in the boiler is not what it should be, and when there are heavy deposits of soot, attention should

be given to the furnace, the draft, the method of handling the fires, and such other points as may suggest themselves, in order to see if the combustion cannot be improved.

36. **COAL AT END OF RUN:** In ending any run of service of the boiler, preparatory to laying it up for cleaning or repairs, the fire should be allowed to die out toward the end of the run,—just enough coal being fired, during the last hour, to keep up steam as long as it is needed. In this way it will be possible to avoid the waste involved in having a large mass of comparatively fresh coal on the grates at the time the boiler is put out of commission. While this point is a minor one, it is worthy of attention.

37. **CLEANING FIRES:** Cleaning the fire of a hand-fired boiler is a somewhat elaborate operation, and it is performed in much the same manner, whether the coal is soft or hard. The present section describes the cleaning of a soft-coal fire, but it applies to hard coal also, save for a few changes that will readily suggest themselves.

The frequency of cleaning that is best adapted to any given plant should be determined by experience, because it will vary with the character of the fuel and with the rate of combustion per square foot of grate area. As a rule, a soft-coal fire needs cleaning oftener than a hard-coal one. The cleaning should be done rapidly, to avoid chilling the boiler unnecessarily, and the damper should be nearly closed, to prevent the entrance of large volumes of cold air through the fire doors. The fire should be allowed to burn low before cleaning.

The free, live, upper part of the front half of the fire, consisting mainly of good coal, should first be worked well back toward the bridge wall. The clinkers, thus left exposed on the front half of the grate, should then be loosened by pushing a slice bar under them, and removed from the furnace. When a dumping grate is used the clinkers are dumped directly into the ash-pit; but if the grate is a stationary one the clinkers must be drawn out through the fire doors and dumped on the floor, where they should be kept well away from the front of the boiler. If hauled out upon the floor, the hot mass should be immediately wet down, preferably with a hose, and special care should be taken to avoid spattering the water against the boiler front, or against any pipe or fitting containing steam or hot water. The bared portion of the grate should next be thoroughly cleaned, for if any lumps are left clinging to the bars the fire will clinker up again more quickly than it will if all such lumps are removed. The spaces between the grate bars should also be cleaned out as well as possible, because if obstructions are left there the flow of air will be correspondingly impeded, and the bars are likely to become warped and burned.

The entire live, active part of the fire should next be pulled forward to the front half of the furnace, and the cleaning operation repeated upon the back half of the grate with the same care as before. If a dumping grate is used, the clinkers are dumped from the back of the furnace into the ash-pit; but if the grate is a stationary one they must be hauled (or "jumped") out over the fire and through the doors. When the entire fire has been cleaned, it should be evenly distributed over the grates and covered with fresh coal. If the furnace has a double door, one side of the fire should be cleaned and allowed to burn up again before the other side is cleaned.

The method of cleaning described above is the one ordinarily employed in American stationary practice; but if the coal clinkers badly it is better to shift the fire sidewise instead of pushing it back. In this way one entire side of the grate is exposed, and it is therefore easier to break up the clinker masses at the back end of the furnace.

38. **ASHES AND ASH-PITS:** The ash-pits should be kept as clean as practicable, because if ashes are allowed to accumulate there, they not only interfere with the combustion by checking the draft, but also lessen the downward radiation of heat from the grate bars, which are then likely to become overheated, warped, and burned.

In plants of considerable size, in which large quantities of coal are burned, it is usually profitable to handle the ashes by a mechanical conveyor of some kind. Conveyors are most commonly employed for this purpose when the coal is handled in like manner, and the boilers are fired by mechanical means.

The ash-pit openings in boiler fronts are often left unprovided with doors. We strongly advise that doors be fitted to them in all cases, because the additional control over the draft that these doors afford is often of extreme value and importance. Under ordinary running conditions, however, the ash-pit doors should be left open and the draft should be controlled by the damper, because this procedure tends to keep the ash-pits cooler, and to prolong the life of the grate bars.

(See also paragraph 42.)

39. **BANKING FIRES:** When the boilers are to be put out of service for a short time, but are nevertheless to be kept hot and ready to be restored to use within a few hours, it is customary to "bank" the fires instead of drawing them or allowing them to burn out. The operation of "banking" consists in disposing of the fires so that they will cease to burn actively, the combustion being reduced to the lowest limit that is compatible with the maintenance of the ignition. In this way unnecessary and wasteful loss of fuel is avoided, while at the same time a large body of intensely hot

coal is maintained in a condition that makes it possible to start up the fire again very easily, and with little loss of time or material.

Fires that are to be banked should first be well cleaned, and a supply of fresh coal should be thrown upon the grates and allowed to become well ignited. The dampers should next be nearly closed, and the fires pushed back against the bridge wall so as to leave the front part of the grates bare. The fires should then be entirely covered with a considerable supply of fresh coal, the front part of the grates being still left bare, however, so that any air that enters the ash-pit may pass up into the furnace freely, and *over* the deadened fire instead of *through* it. Some firemen haul the fire *forward*, and bank it in a windrow across the front of the furnace. It will keep best if covered with fine, damp coal, well tamped down; for a crust then forms over it which excludes the air so effectively that the fire will often remain alive for two or three days.

Coal-gas is slowly distilled off from a banked fire, and to guard against accident from the ignition of explosive mixtures of gas and air in the furnace and the passages connected with it, care should be taken to ensure sufficient ventilation of the furnace and its connections by permitting a small quantity of air to stream continuously up through these spaces and out into the stack. The ash-pit doors should be closed tightly, and the damper in the uptake of the boiler should be as nearly closed as is compatible with the maintenance of the ventilation to which we have just referred. To guard against the accumulation of explosive gas mixtures, dampers are usually perforated so that they will pass a small amount of air even when they are set squarely across the uptake, and when such a perforation exists it will usually afford sufficient protection against gas explosions, provided a circulation through the furnace is made possible by admitting a slight amount of air above the grates. The fire doors should therefore be opened by a mere crack, if the furnace is of the usual type; but if it is built with a hollow bridge wall as explained in paragraph 20, the air needed for ventilating the setting may be admitted by way of the bridge wall openings.

The present section on banked fires relates to hand-fired boilers with furnaces of the usual type. When the boilers are mechanically fired, or the furnaces are of special forms, it will be necessary to modify the procedure accordingly. The main principles that are here explained will apply equally, however, in all cases; and it will usually be an easy matter to make such changes in the details of the operation as the prevailing conditions may require.

40. WETTING THE COAL WITH PLAIN WATER: Wetting coal to some extent, before it is thrown into the furnace, is an almost universal practice. It does not appear to be based upon any sound theoretical principle, but it is so firmly established by practice and tradition that attempts have been made to find some theoretical justification for it. The usual explanation offered by educated and intelligent firemen is, that water consists of oxygen and hydrogen, and that the coal takes the oxygen from the water and liberates the hydrogen, which afterwards burns in the furnace. No doubt this action is possible, and in fact it certainly occurs under suitable conditions. It cannot lead to any gain in heat, however, because the amount of heat that is required to separate the hydrogen of the water from the oxygen with which it is combined, is exactly the same as the amount that is afterwards obtained by the complete burning of the hydrogen in the furnace; and if some portion of the liberated hydrogen gas should happen to escape into the chimney, unburned, there would be an actual *loss* of heat, instead of a gain. Furthermore since hydrogen, in burning, becomes again transformed into water-vapor, the water that is added to the coal must eventually pass up the chimney in the form of steam, whether the firemen's theory is sound or not; and hence, in any case, the wetting involves the loss of as much heat as would be required to evaporate the water that is used, and turn it into steam at atmospheric pressure, and superheated to the temperature of the chimney gases. If there is a rational justification for the wetting of the coal, it is doubtless physical in nature, and not chemical. For example, moisture makes the small, loose particles of coal adhere to one another and to the larger lumps, and it hence tends to prevent fine, dust-like particles from being drawn up the chimney by the draft, unburned. Firemen also assert (and we are inclined to believe they are right) that moisture tends to lessen the formation of clinker-masses, and to make them softer, so that they can be broken up more easily.

41. **POWDERS AND WASHES:** Various powders and liquids are offered for sale, from time to time, with the assurance that if they are sprinkled over the coal, they will produce a marked improvement in the performance of the boiler. We do not wish to question the good faith of the inventors of these substances, yet we deem it advisable to say that it is entirely impossible to increase the economy of a boiler by any such method whatsoever. These substances may make the fire in the furnace look brighter and hotter, but they are of no real economic value. There is nothing mysterious or occult about combustion. It consists merely in the rapid combination of the fuel with oxygen gas, and since the oxygen of the air is free, there is no conceivable advantage in obtaining it from some other source for which we have to pay.

42. **BURNING ASHES:** There is always more or less unconsumed coal in the ashes that are

removed from the boiler, and this coal, if it were separated from the ashes with which it is mixed, would be available for further use as fuel. Except for this slight proportion of coal that has slipped through the grates, ashes are entirely incombustible. They are what is left, after everything has burned that *will* burn. The compounds that are placed upon the market and which, when mingled with ashes, are supposed to make them available as a fuel for the further production of steam, are absolutely without value.

43. **MECHANICAL STOKERS:** The firing of coal by mechanical means is now favored, in American practice, much more generally than it was a few years ago. The prejudice against mechanical firing that formerly prevailed has largely disappeared, and greater weight is now accorded to the fact that in large power installations, where conditions are favorable to their use, mechanical stokers of approved form may promote economy in several distinct ways. They obviously reduce the cost of labor, by firing the boilers with a smaller amount of manual work. They also make it possible for the combustion to proceed under ideal conditions, because they introduce the coal, either continuously or in small charges at short intervals, without admitting cold air at the fire doors or elsewhere.

Mechanical stokers are made in many different styles. The types in which the coal is fed to the furnace from below the fire line are collectively known as "underfeed stokers", and in the best known representatives of this class, in the United States, the coal is introduced into the furnace by a system of plungers. This form is well adapted for use with forced draft, and with hard coal or with mixtures of hard and soft coal. Stokers of certain other types are fed by means of screws. Others have reciprocating bars, by means of which the coal, as it burns, is made to travel slowly from the front end of the grate to the back end, or down the length of an inclined grate. The type known as the "sprinkling stoker" is rarely seen in this country, but in the Midlands District, in England, it has been successfully used for many years for burning soft-coal slack. In this form the fire is kept fairly thick, and the feed is actuated by two cams that throw the coal alternately to the front and the back of the furnace, sprinkling it on uniformly so that the combustion proceeds properly and efficiently over the entire grate. Cams are also used for firing hard-coal waste.

The traveling grate (or chain grate) that is often used in connection with stokers of certain types, consists of a series of bars that are hinged together and connected so as to form a sort of endless chain, which travels slowly along the entire length of the furnace. The rate of progression is supposed to be regulated so that the fresh fuel that is placed upon the grate at the front end will be completely burned by the time it reaches the back end. When this condition is realized, and a given set of bars reaches the rear roller and tips downward for the return passage, nothing remains upon it but the incombustible matter that was contained in the coal with which it was at first loaded.

In plants that are provided with mechanical stokers, there is usually a fairly complete apparatus for handling the coal and the ashes by means of conveyors, many different types of conveyors being used for this purpose. The coal is usually stored in overhead bunkers, and is fed by gravity into hoppers that are located above the stoker mechanism.

All the types of stokers that we have mentioned are in the market, as well as numerous others to which we have made no explicit reference, and each one is subject to limitations peculiar to itself. The right type for any given plant can be selected only by taking account of all the conditions under which the work is to be done, including the character of the coal, the nature and mode of variation of the load, and many other items that space does not permit us to enumerate. It is plain, therefore, that no choice should be made until the matter has been referred to an expert familiar with the stoker problem, and with the many conditions upon which the efficient working of the apparatus depends. Advice upon these points should therefore be obtained from a competent and disinterested source before installing mechanical stokers of any kind.

44. SELECTION OF FEED WATER: It sometimes happens that there is only one available source of water for use in the boilers, and in this case it is necessary to make the best of what can be had, even if it is bad. Several sources are usually available, however, and when this is the case, careful consideration should be given to their relative merits. It is highly important to avoid water that will corrode the boilers, either because it is acid or because it contains organic matter such as might be derived from drainage. A second consideration in the selection of feed water should be its likelihood of producing troublesome boiler scale. Water can be treated for the removal of the scale matter that it holds in solution, but it is better to take considerable care to secure a supply that is relatively free from scale-forming elements, rather than to go to the trouble and expense of purifying a supply that is objectionable in this respect. Boiler owners often hesitate to use city water on account of its cost, preferring to sink wells of their own or to draw water from some other convenient source that is free. An intelligent decision on this point is not always easy to reach, because the mere fact that the city water has a higher first cost is not sufficient to determine the advisability of using it. The manufacturer who sinks a well may find that the water from it is heavily loaded with dissolved lime or magnesia, and that it will give a heavy deposit of scale which will lower the efficiency of the boiler and increase the cost of keeping it clean. The deterioration of the boiler will also be more rapid when running with the cheap, scale-forming water, than when running with city water at a higher cost. The question of using city water or some substitute having a smaller first cost, is so complicated that the opinion of some authority having had large experience in these matters should be taken before coming to a decision. The Travelers Indemnity Company is always ready and glad to give advice to its patrons on this point, and its chemical department is prepared to give expert opinions upon all such matters.

45. SOURCE AND FORMATION OF SCALE: The deposits that are commonly met with in boilers are of two general kinds, distinguished as "sediment" and "scale", respectively. "Sediment" is formed by the settling of particles of solid matter that were previously held in suspension in the water. It is soft and mud-like when first formed, and although it may become baked and hardened to some extent it rarely becomes actually stony when present alone. But in the presence of loose fragments of solid matter it often acts as a sort of binding medium, cementing them together into masses that are suggestive of some of the forms of conglomerate rock that are met with in nature. "Scale", in the proper sense of the word, is a hard, more or less stone-like coating, that is formed upon the heating surfaces of the boiler by the deposition of mineral matter that is in solution in the feed water when it enters the boiler. The mineral substances of which it is composed are obtained from the soil, being dissolved by the water as it percolates through the ground and comes in contact with various rocks and minerals. When the water is pumped into the boiler and evaporated, some of the constituents are thrown down by the simple act of heating, and others remain in solution until some considerable part of the water has been evaporated and the solution thereby concentrated to the saturation point. Any further evaporation must be followed by a deposition of some of the dissolved matter, because the steam cannot carry any of it away.

46. **KINDS OF SCALE:** Boiler scale is very common, and more or less of it is quite sure to be formed unless the water is unusually soft and pure. It varies greatly in composition, but its chief constituents are usually sulphate of lime, carbonate of lime, and carbonate of magnesia. Chloride of magnesia and sulphate of magnesia also occur more or less frequently, and these are particularly objectionable because they are corrosive and tend to attack the metal of the boiler. The physical constitution of the scale varies greatly, and two samples of similar chemical composition will sometimes differ a great deal in hardness and porosity. Sulphate of lime usually makes a hard, stony scale when

it is present alone, or when it is the chief constituent. Carbonate of lime, under ordinary conditions, forms a soft scale in horizontal tubular boilers, though it often takes a hard form in heaters and in water-tube boilers. It is rare to find a scale composed of any one substance alone, however. Various substances are usually present in it, mixed in varying proportions, and combined also with sand, clay, iron-rust, and other sedimentary deposits. Boiler scale tends to deposit wherever the circulation in the boiler is sluggish, and where the heat is greatest and the evaporation most rapid. Scale that is formed in the upper parts of the boiler also becomes dislodged from time to time, falling down upon the lower parts, where, if not removed at proper intervals, it is apt to become cemented together in a compact mass, which not only diminishes the efficiency of the boiler, but also causes it, in many cases, to become badly damaged by overheating.

47. EFFECT OF SCALE UPON EFFICIENCY: The stony matter and muddy deposits that form upon boiler shells and tubes are poor conductors of heat as compared with the metal of the boiler, and hence they tend to diminish the efficiency of the boiler by lessening the absorption of heat. There is a good deal of misinformation to be had on this point from the books that have been written about boilers and boiler practice. Thus it is often taught that a coating of scale 1/16 of an inch thick diminishes the efficiency of the boiler by 25 per cent., similarly definite statements, showing a further rapid decline of efficiency, being made for greater thicknesses. If the figures that are usually given were correct, it would follow that the boilers of the United States, as a class, are very wasteful indeed: for it is unusual to find a boiler that has not a scale at least 1/16 of an inch thick upon it, except in regions where the feed water is quite soft and pure. There is no doubt about scale diminishing the efficiency of the boiler, but the loss cannot be stated in any simple way, because it varies a great deal according to the character of the scale. If the scale is compact and impervious to water, as is usually the case when it is composed of lime sulphate, the loss of efficiency may be considerable; while if it is quite porous, so that water can percolate through it easily, the loss may be sensibly less. The boiler should be kept as clean as possible, at all times;—not only because the scale diminishes the efficiency, but also because it is often a source of acute danger, since it tends to damage the boiler by causing the metal to become overheated and burned.

48. SCALE SOLVENTS AND PREVENTATIVES: In operating boilers with a water that contains scale-forming substances, it is usual to introduce chemicals of one kind or another, either to prevent these substances from producing a hard coating that will be injurious to the boilers and detrimental to their efficiency, or to dissolve away such coatings after they have been formed. If the quantity of scale-forming matter in the water is large, however, we strongly advise removing as much of it as possible by treating the water before pumping it into the boiler; for it is far better to keep the objectionable substances out of the boiler altogether than it is to put them in and treat them afterwards. (See paragraph 60, below.) When the water is to be treated inside the boiler, the chemicals that are used for this purpose should be dissolved (if they are bought in a solid form, and if it is possible to dissolve them) and pumped into the boiler with the regular feed. If they are in the form of insoluble powders, like tannin or some of its derivatives, they may be introduced through the manhole, or stirred up in the water until they are held freely in suspension in it, and then introduced by a pump. Fluids may be mixed with the feed in quantity, or they may be introduced into it, drop by drop, by some form of sight-feed apparatus. In all cases the substance that is used for the treatment of the scale should be introduced continuously and in the proper proportions, in order to obtain the best results. Most of the scale preventatives act by transforming the matter that produces the stony deposit into some other chemical form, which either remains dissolved in the water until a much higher degree of concentration is attained, or else is thrown down in a form that is easy to remove from the boiler. Some of them, however, like kerosene, have no chemical effect at all, but act either by causing the old adherent scale to flake off, or by influencing the newly-forming scale so that it is deposited in a more manageable form. The ideal way to use a scale preventative is to find out, first, how much of it should be used to each hundred gallons of water, and then to introduce it with the water as uniformly as possible, and in the proper amounts as determined by measurement. The chemical substances that are oftenest used in the treatment of boiler scale are considered below.

49. **SODA ASH:** This is chemically the same as washing soda, although it is usually sold in the form of a dry powder instead of in the crystalline condition. It is technically known as "crude" carbonate of soda, although it is often more than 98 per cent. pure. Soda ash is cheap, and as it is effective for quite a large proportion of the scale troubles that occur in boilers, it is by all odds the commonest substance used in the treatment of feed water. Many of the proprietary substances that are sold for this purpose contain soda ash, in fact, as their most important constituent. Soda ash is most useful when the scale to be treated consists chiefly of sulphate of lime, because it decomposes this substance and transforms it into carbonate of lime which

is ordinarily much more porous, and more easily removed from the boiler. The statement that carbonate of lime forms porous scale, and that it is easily removed from boilers, cannot be properly made without qualification, however, for while it is true of the ordinary horizontal tubular boiler, yet in water-tube boilers and upright boilers, carbonate of lime often forms a hard scale, similar in texture to that which is produced by lime sulphate. It sometimes happens that feed water contains a large amount of sulphate of soda as one of its natural constituents, and in such cases no compound of soda can be used advantageously in any considerable quantity, because it would introduce too large a proportion of sulphate of soda and cause the boiler to foam. Under these circumstances witherite may be recommended as a substitute for the soda. (See the last part of paragraph 58.)

50. **CAUSTIC SODA:** Caustic soda is far more effective in the treatment of boiler scale than soda ash, but it costs more, and for this reason among others, soda ash should be considered before caustic soda is adopted. This is usually a matter to be decided by a chemist who has made an analysis of the water beforehand. When there are questions of this kind to be determined, THE TRAVELERS INDEMNITY COMPANY makes analyses of feed water for its assured, without charge, and gives them advice as to the most advan-

tageous substance to use and the quantity that it is advisable to introduce. Care should always be taken to avoid using an unnecessary amount of caustic soda, not only because of the expense involved, but also because this substance, when used in excess, is apt to find its way into the steam pipe and even over into the engines, and it may give trouble by attacking gaskets and packings.

Great care should be taken in the use of caustic soda, because the substance itself, and its solutions also, are corrosive in their action upon the skin, and excite violent inflammation if they get into the eye. Where caustic soda is used it is well to have on hand some clean absorbent cotton and an eight-ounce bottle containing two ounces of vinegar and enough water to fill the bottle. If caustic soda should by chance get into the eye, it should be washed out *at once* by pulling down the lower lid of the eye and flushing the eye thoroughly with clean water pressed out from a wad of absorbent cotton. A minute or two should be spent in this flushing process, during which it is well to allow the patient to close his eye now and then, to permit the water to become better distributed over the eye. Then flush the eye with the vinegar solution, using the same method described above. In this way the caustic soda will be neutralized without danger, and the injury to the eye will be minimized. After an accident of this kind the injured person should immediately go to a physician for further treatment, an eye specialist being greatly preferable if he is at hand.

Solid caustic soda rapidly absorbs moisture from the air and becomes inconvenient to handle. Solutions of caustic soda, and the solid caustic itself after it has become sticky or semi-fluid from the absorption of moisture, also take up carbonic acid gas from the air and become gradually converted into a solution of soda ash. Hence the caustic, whatever its form, should be kept constantly covered and protected from the air. Caustic soda should always be stored in the care of some one responsible man, and it should be plainly labelled, and conspicuously marked "POISON".

51. **SODA MIXTURES:** It often happens that soda ash is not quite sufficient to take care of the scale in a boiler, while at the same time caustic soda, in full strength, does not appear to be required. In such instances the two are often mixed,—the proper proportion for good results being determined by a chemist, from an analysis of the feed water. In this way the cost of the treatment is kept as low as possible, and yet the treatment itself is made effective. A mixture of lime and soda ash can also be used, many times, with distinct advantage.

52. **SODIUM PHOSPHATE:** Phosphoric acid forms three distinct compounds with soda, which

differ from one another merely in the proportion of soda that is present. The particular compound that is mainly used in the treatment of boiler waters is known as "tri-sodium phosphate", the syllable "tri" referring to the fact that each molecule of the compound contains three atoms of sodium. Tri-sodium phosphate is an ideal substance for the treatment of boiler scale, in every respect except as regards expense. To be effective, it must be used in larger quantities than its advocates usually recommend, and when so used it is much more expensive than soda ash, and considerably more expensive than caustic soda. In some cases in which cost is not the governing consideration, it can be used to great advantage.

53. **SAL AMMONIAC:** This substance would be practically perfect for the treatment of boiler scale, except for the fact that it is very corrosive, and would certainly do great damage to the boiler, if it were present in the smallest excess. Young and inexperienced persons occasionally recommend it, but no competent chemist or engineer would consider it for a moment, unless possibly in some special case where it was to be used under his own immediate and personal observation and control.

54. **TANNIN:** Tannin is used to some extent for the control of boiler scale, though it is too expensive

to be employed in the pure state. It is usually introduced in the form of bark extract, catechu, or some similar substance, containing a considerable amount of tannin in addition to large quantities of more or less inert substances. Care should be exercised to avoid *excess* of tannin, for if there is enough of it present to more than control the lime and other scale matters, the excess combines with the metal of the boiler to some extent, forming a densely black inky substance. All the compounds that are sold as tannates contain mineral matter in addition to their organic tannin, and none of them is purely vegetable. The mineral matter that they contain is largely soda ash; and the soda ash, when present in quantity, is an essential element in the action of the compound. The inert organic matter that accompanies the tannin in bark extract and certain of the other tannin-bearing substances is likely to give trouble by producing foaming and priming, if the compound is used in any great quantity.

55. **CRUDE OIL:** Crude petroleum has been extensively recommended for the removal of scale from boilers, and there is no doubt that it is often effective. We do not advise it, however, because the crude product contains a certain proportion of heavy oils, and in the boiler a process of fractional distillation occurs, the lighter constituents of the crude oil evaporating and passing away with the steam, while the heavier ones

remain behind and often form coatings upon the boiler, which lead to the overheating and bulging of the plates. (See paragraph 72, below.) It is much better to use kerosene, if some form of mineral oil treatment is to be adopted, because the kerosene is just as effective as the crude oil, and although it costs a little more, the difference is insignificant in comparison with the danger of damage to the boiler from the crude oil. (The cautions that are given in paragraph 67 of this pamphlet, with regard to the dangers of kerosene, apply with even greater force to crude oil, when it is used in the boiler in any way whatever.)

56. **CONTINUOUS USE OF KEROSENE:** Many authorities treat boilers for scale by introducing kerosene with the feed, drop by drop, by means of some form of sight-feed apparatus, or introducing it in small quantities in some other way, at frequent intervals. Kerosene does not have any chemical effect upon the scale, and some maintain that it is without any very valuable effect of any kind. The prevailing opinion appears to be, however, that it modifies, to some extent, the form in which the scale matter is deposited, causing it to be more granular, so that it can be removed from the boiler more easily The cautions that are given in paragraph 67 of this pamphlet with regard to the dangers involved in using kerosene in quantity, apply also when it is used by the continuous drop method.

57. **GRAPHITE:** Opinions differ with regard to the efficacy of graphite in the treatment of boiler scale, even more than they do with regard to the efficacy of kerosene when applied by the drop method. Some authorities maintain that graphite is without any special value in the treatment of scale, and others maintain that it is one of the finest substances that can be employed. Graphite has no chemical action upon the scale, but the claim is made that it mingles with the scale-forming matter in such a way as to lessen its adhesion to the boiler. When it is used in excessive quantities, however, or is not sufficiently fine to remain in suspension in the water, it may form a sludge on the heating surfaces of the boiler, and so lead to the burning and bulging of the plates and tubes. If graphite is used, it should be applied with caution and under the observation and direction of a man of good judgment, so that overheating and burning of the boiler may be avoided.

58. **MISCELLANEOUS SUBSTANCES:** The greatest imaginable variety of things has been suggested and used for preventing the formation of scale, or for influencing the form in which it is deposited. Potatoes, for example, have been employed for this purpose the idea being that when they cook up and become disseminated through the boiler, they form a slippery coating upon the lime particles and lessen their

power of adhering either to one another or to the boiler. We strongly discountenance the use of potatoes in this way, not only because there is danger of their forming a sludge on the bottom of the boiler and so producing overheating, but also because any considerable quantity of boiled potato in the boiler is pretty sure to lead to foaming. Glucose forms a soluble compound with lime, and for that reason it has often been advocated as a scale solvent and preventative, and it is a constituent of some of the proprietary compounds that are sold for the treatment of boiler scale. Glucose should be used either very guardedly or not at all. If there is more of it present than is required to take care of the lime, the excess is likely to become decomposed under the influence of the heat of the boiler with the formation of organic acids that will corrode the metal. Molasses has also been used as a scale preventative, its effectiveness depending upon the presence of the sugar that it contains. Its action is similar to that of glucose, and there are the same objections to it that have been urged against glucose;—namely, that if it is used in sufficient quantity to really affect the scale, it is likely to become decomposed with the formation of corrosive organic acids. We strongly recommend that all these unscientific and freak-like scale solvents and preventatives be avoided. THE TRAVELERS is always glad to advise its patrons with regard to the scale problem, and to recommend solvents and methods of treatment that will be adapted to each special case, and in conformity with the best engineering practice of the day.

One of the most troublesome problems to deal with, in the treatment of boiler scale, is the one which arises when the water is heavily charged with sulphate of lime, and steam has to be used for special purposes where (as in breweries) the presence of even a small quantity of a strong alkali like soda ash or caustic soda would be objectionable. In such cases the mineral known as "witherite" may be used with distinct advantage. It is a native carbonate of barium, and it decomposes the lime sulphate without giving the water the objectionable alkalinity that is communicated to it by most of the available boiler compounds and scale preventatives.

59. NEW PROCESSES AND DEVICES: New and often curious processes and devices, previously unknown to the engineering world, are offered to steam users from time to time, by inventors and promoters who claim that they will prevent the formation of scale, or lessen the quantity of it, or cause it to take such a form that it can be readily removed from the boiler. Collectively considered, these novel methods are of very doubtful value. When a new invention is proposed for adoption,—even though it is to be put in on trial, without a direct charge being made,—it is better to decline it, and to let some other person do the experimenting and find out whether the thing really has merit or not. This advice is not prompted by an unprogressive spirit. It is merely good, hard, engineering sense. It is better to await the verdict of extended experience, rather than to take the chance of wasting fuel and perhaps injuring the boiler.

60. EXTERNAL PURIFICATION OF WATER: It is more scientific to purify the water before it enters the boiler, than it is to follow the commoner plan of introducing it, with all its dissolved solids, and treating it after it is inside of the boiler. External purification is therefore strongly favored by modern engineers, whenever the conditions warrant it, and a number of effective forms of apparatus for purifying boiler feed water are on the market. A water-purification apparatus, in order to be really efficient and practical, should be supervised by some reliable person upon whom entire dependence can be placed, and this is not always feasible in a small plant. In larger plants, however, a reasonable expenditure for such supervision will usually be a good investment, if the water is of such a character that external purification appears to be advisable. A water that contains a large amount of carbonate of lime can be treated with advantage before it is pumped into the boiler by merely adding caustic lime,—the substance that is known in commerce simply as "lime", and which is slaked (or "slacked") to make mortar. The operation should be performed in a tank, and the water should be warmed by a coil of steam pipe. It need not be really *hot*, however. This process is cheap, and is quite effective for the removal of lime carbonate. The chemical action is simple, consisting in the mere absorption, by the caustic lime, of any free carbonic acid gas that may be present in the water. When this is removed, the greater part of the lime carbonate is also precipitated, and the water should then be filtered, or allowed to stand quietly for a sufficient time in a large settling tank. All the tanks that are used should be located in warm places, or be otherwise protected from radiation, to avoid losing the heat that the water receives from the steam coil in the caustic-lime tank.

61. **FREQUENCY OF CLEANING:** The frequency with which boilers must be opened up and cleaned internally varies greatly, and depends upon the conditions that prevail in the plant. Hence no very definite recommendations can be made on this point, which could be followed generally. It is often necessary to open the boilers and clean them every week, when the water is bad and the boilers are pushed to the limit of their economical capacity; whereas in other cases it may be sufficient to clean them once a month, or even as infrequently as once in two or three months, if the water is particularly good. The man

in charge of the boilers will be able to judge on these points if he is skilled at his work, and the boiler inspector will also be able to give useful advice, because he is familiar with the conditions that prevail at the plant, and he also knows what experience has shown to be good practice in other plants using similar water. Cleaning should be done oftener in dry seasons than in wet ones, because when there is but little rainfall the feed water is apt to be more nearly saturated with solid matter, and a given quantity of water will therefore deposit more scale and sediment at such times.

Cleaning should also be more frequent than usual immediately *after* a dry season, and likewise when there have been copious rains, or the winter snows have melted and swollen the streams and springs. (This point is explained below, in paragraph 69.)

62. **METHODS OF CLEANING:** The best way to do the cleaning depends to a large extent upon the nature of the deposit. Some of the commoner methods are outlined below, and their relative degrees of applicability and importance must be judged by reference to local conditions, and by the knowledge that the man in charge has of the boilers themselves. The counsel of the inspector will be found especially valuable here also, as he has watched and studied many more boilers than the local man, and is therefore in a position to know better what methods are most likely to be needful and efficacious.

63. **USE OF THE BLOWOFF:** A considerable part of the loose deposit that collects in the bottom of the boiler may be removed by an intelligent use of the blowoff, whether this deposit consists simply of mud, or also includes small pieces of scale that have formed in higher parts of the boiler and have flaked off and fallen down. When the boiler is in regular operation the water in it is in active circulation, and particles of mud and other kinds of solid matter are whirled around with it continuously, and distributed throughout its entire bulk. If the blowoff valve is opened under these conditions it removes only that part of the circulating deposit which is held in suspension in the water that is drawn off. But when the boiler has been standing idle for a time, without steam being drawn from it, the suspended solid matter gradually settles toward the bottom until it either lies against the lower surfaces of the boiler in the form of an actual mud, or floats close to them as a very thin fluid paste. This condition is most likely to be realized when the boiler has been quiescent for a considerable time, as for example in the morning, after it has lain idle all night. If the blowoff valve is opened for a few moments under these circumstances, before starting up the draft and stimulating the circulation, quite a sensible part of the deposit that has settled will be blown out. The valve should be opened wide, so that there may be a good strong current through the pipe, because much better

results are obtained in this way than can be had by opening it by a smaller amount for a longer time; and it should stand open long enough under average conditions, to blow down about one gage of water from the glass. In opening and closing the blowoff valve, special care should be exercised not to do it quickly. The valve should be slowly opened and slowly closed, and it is of special importance that the *closing* should be slow, for unless careful attention is given to this point there is likely to be an accident from the production of a water-hammer effect due to the sudden checking of the column of water that is rushing out at high speed. The action in such a case is closely like that which occurs in the hydraulic ram, and many serious consequences have followed from the shocks to which boilers have been subjected in this way.

The frequency with which the blowoff should be opened, and the quantity of water that should be removed by means of it, will naturally vary with the nature of the feed water and the duty that the boiler has to perform; but even when using good soft water the valve should be opened once a day, if only for a few moments, so that the blowoff pipe may be kept well flushed out.

It may sometimes be advisable to use the blowoff freely, even when there is no sensible deposit of sediment; because as the evaporation proceeds the water in the boiler becomes more and more nearly saturated with the scale-forming matter that it holds in solution, and by blowing off 100 or 200 gallons and then pumping in an equal amount of fresh water, the degree of concentration of the water in the boiler becomes somewhat reduced. Repeated blowing and feeding, in this way, is an effective remedy for foaming in boilers, from the presence of excessive organic matter.

64. **WASHING OUT:** When a boiler is opened up for cleaning, a considerable amount of the loose sediment that is deposited within it may be removed by simple washing. This should be done with a hose throwing a strong stream of water, and the stream should be directed against all parts of the boiler. The boiler should be cool before the hose is applied. If time cannot be given for it to cool down properly, the washing should be done with warm water. Severe strains, accompanied by the development of leaks about the tube-ends and joints, are often caused by the action of cold water on a warm boiler. The washing should be done both from above and from below, and in fact from all the openings from which the boiler is accessible. If a horizontal tubular boiler is washed out from the handholes only, there will be a considerable amount of deposit on the upper sides of the tubes that will not be removed, because it cannot be reached by the stream of water. A boiler should be washed out not only to remove sediment, but also to

remove any loosened scale that may remain after cleaning out the major part of the deposit by the various other methods that are mentioned below. Special care should be taken to thoroughly clean all mud drums and other similar parts in which the circulation is likely to be poor even when the boiler is in active service, or which lie at a low level.

To make sure that all the loose scale has been removed, and that no tools have been left behind, all parts of the interior of the boiler should be examined with a good light before the openings are closed up again.

65. **CLEANING WITH TOOLS:** To remove scale that adheres to the boiler too closely to be washed off with a hose, it is often necessary to chip the scale off from the plates and tubes by hand, employing special tools that are appropriate to the work. The removal of scale from water-tube boilers is especially important, because if the tubes are not kept clean they are likely to become overheated and burned, splitting and bursting often being the result. Various forms of scrapers, hammers, and cutters are used to remove the scale from such tubes, some being operated by hand and others by steam, air, or water. In using a form of tube cleaner that loosens the scale by striking blows upon it or upon the tube, care should be taken not to operate the device by any greater pressure than is

required to do the work, nor to allow it to operate for more than a few seconds in any one place; because there is danger of damaging the tube by the cumulative effect of the repeated blows if these precautions are not taken.

The need for mechanical cleaning can be reduced in great measure, or even obviated entirely, by proper treatment of the feed water.

66. **KEROSENE SPRAY:** Kerosene can often be made quite effective in causing hard, stony scale to flake off from the shell and tubes of a boiler. It will not penetrate wet scale to advantage, but when the scale is dry the kerosene works in between the scale and the metal and causes the two to separate. To apply the kerosene properly the boiler should be emptied while still warm, and allowed to stand for a short time until the heat radiated from the walls of the setting has dried the scale out. The kerosene should then be sprayed into the boiler in generous quantities, so that every part where scale may be lodged shall become thoroughly drenched. Upon standing for a time after a treatment of this sort, the scale will be found to be loosened up so that striking on the boiler or on the tubes with a hammer will loosen it in large quantities and cause it to fall off. (Note the cautions given in paragraph 67, however.) After an application of kerosene spray the boiler should receive an especially thorough cleaning, every accessible part being scraped or chipped to remove all the scale

that can be reached, and before closing the boiler up it should be finally washed out with special care. These precautions are of the highest importance, because if they are neglected a considerable part of the scale that still adheres to the shell and the tubes when the boiler is closed up, will almost certainly flake off and fall down upon the heating surfaces soon after the boiler is restored to service, and overheating and burning and bulging are very apt to result. Moreover, after kerosene treatment the boiler should be opened up again and cleaned, much sooner than it would otherwise need to be, in order to remove the loose scale that is sure to flake off from places that are not readily accessible.

Deposits of hard, stony scale in the tubes of water-tube boilers may be loosened by soaking them, when dry, with kerosene applied by a mop attached to the end of a long pole. When this course is followed it is important to heed the advice given above about thorough and frequent cleaning and the removal of loose scale, as well as the cautions given in paragraph 67 with regard to the dangers of kerosene.

67. **CAUTION IN USING KEROSENE:** Kerosene should not be used, as described above, without a thorough understanding of the dangers that are involved, and when it is so used the operation should be directed by a man to whom these dangers are entirely

familiar. It should never be used, in fact, except as a last resort, when other means of achieving the desired end have been faithfully tried and found to be ineffective. When kerosene is sprayed into a warm boiler, or even into one that is cool, a vapor is formed which mingles with the air in the boiler and produces a mixture that may be dangerously explosive. Special care should be taken to keep all lights away from a boiler that is undergoing treatment, except incandescent electric lamps; and when an incandescent lamp is used, it should be thoroughly protected against accidental breakage by enclosing it in a substantial wire cage. After the boiler has been treated with kerosene it should not be entered, even without a light, until the fumes of the kerosene have been removed; for these fumes are likely not only to burn or explode, but also to overpower the attendant if he goes into the boiler. When the boiler has stood idle for a sufficient length of time, with the kerosene sprayed upon its inner surfaces, it should be washed out *very thoroughly* with a hose and a liberal excess of water; and after it has been so washed it should be thoroughly ventilated before any attempt is made to enter it or to bring an open light near it. Even after the boiler has been washed, ventilated, cleaned, filled up, and returned to service, it may be that the danger is not entirely removed, and it is always safest to ventilate it thoroughly the next time it is opened before allowing an open light to be used about it.

Kerosene should never be applied to a boiler in quantity,—either for spraying or for scrubbing out or in any other way,—*while other boilers in the same room are still in service.*

When kerosene is introduced into the boiler, drop by drop or in other small quantities, for the treatment of scale, it is important to ventilate the boiler thoroughly when it is next opened up, before permitting any person to bring a light near it. Men have been seriously injured by neglecting this simple precaution, which is often (though erroneously) declared to be foolish and unnecessary.

68. **BOILING OUT:** When a boiler has become badly coated with scale, through neglect or through the protracted use of bad feed water, it is sometimes desirable to clean it by the method technically known as "boiling out". In applying the "boiling out" process the boiler is filled with water to a point higher than the upper limit of the scale deposit, and a liberal amount of soda ash is then added. The quantity of soda ash that it is advisable to use depends upon the size of the boiler, and upon its condition. For a 72-inch horizontal tubular boiler 30 or 40 pounds of soda ash may often be used with advantage. The efficiency of the treatment is increased by adding to the soda ash about one-tenth of its own weight of caustic soda. Many engineers also favor adding two or three gallons

of kerosene oil. The soda ash—and the caustic soda also, if it is used,—should be dissolved before it is put into the boiler.

When the boiler has been filled as described above, and the soda ash and other constituents have been introduced, a slow fire should be built in the furnace and maintained there for two or three days, the heat being regulated so that the water in the boiler will be kept boiling gently but not violently. In applying this treatment the manhole should always be left open, so that no steam pressure can accumulate in the boiler, or the same purpose should be accomplished in some other equally effective and positive way; and if caustic soda or kerosene is used, all the precautions that are mentioned in paragraphs 50 and 67 should be faithfully observed.

After the boiler has been treated as here described, it should be emptied and washed out with a hose; and if kerosene has been used, the boiler should also be thoroughly ventilated before an open light is permitted to come near it, and before anyone enters it. We greatly prefer to avoid the use of kerosene in "boiling-out" operations, especially when the conditions are such that the oil-vapor that comes away from the boiler must escape into the boiler room; for there is always more or less likelihood that the vapors that are thus distilled off will take fire explosively at one of the furnaces, or in some other way. If kerosene is used a conduit of some kind should be provided, to conduct the oil-vapors from the manhole opening to the outer air, without permitting them to escape into the boiler room.

When the boiler has been emptied, washed, and ventilated, the scale that has been loosened by the boiling-out process should be carefully removed, and the entire interior should be cleaned as thoroughly as possible, by hand tools and in other ways. Particular care should be taken to remove all scale that may have collected on the bottom of the shell, or upon other parts that are exposed to a high temperature; and after the boiler has been restored to service it should be opened up far oftener than usual, for a considerable time; because much of the scale that still adheres to it is likely to become loosened in service, and to fall down upon the fire sheets and other heating surfaces, to the great detriment of the boiler. (Compare paragraph 70.) In water-tube boilers the same care should be exercised to clean the tubes and other parts, after the boiler has been subjected to the treatment described above.

Boilers should never be allowed to become scaled to such an extent as to require "boiling out". If the feed water is bad, a new and better supply should be obtained, if possible; and if a change of this kind is not practicable, the water should be purified before it is admitted to the boiler. (See paragraph 60.)

69. **CHANGE TO PURER WATER:** When a boiler is run for a long time with water of one kind, scale will accumulate within it to some extent, however faithfully the cleaning may have been done by the man in charge, because certain parts of it are practically inaccessible. If a change is then made from the regular feed water to some supply that is purer, the purer water will usually dissolve a part of the scale that is present, and will almost certainly soak under a considerable part of the rest, causing it to fall down and lodge upon the heating surfaces of the boiler. This action may take place either from a conscious and intentional change in the source of water or as the result of a natural softening of the regular supply, due to heavy rainfalls or to the melting of snow in the spring.

70. **LOOSE SCALE:** In the normal and regular operation of the boilers a certain amount of sediment and deposit will collect within them, and more or less scale that has formed elsewhere will become detached from the sheets and tubes and will accumulate in piles and layers in the lowest parts of the boilers. The quantity of loose scale thus thrown down will be materially greater when the boiler has been recently boiled out or sprayed with kerosene or treated with an unusual amount of solvent, or when (as explained in paragraph 69) the feed water has become softer. It is therefore important, in all such cases, to open up the boiler much

oftener than usual, and to remove the loose scale from all the accessible parts, and particularly from the heating surfaces. Otherwise there is serious danger of the boiler becoming badly bagged or burned.

71. **MISCELLANEOUS DEPOSITS:** Deposits of many other kinds are met with in boilers from time to time. Wood pulp coming down the stream from paper mills situated at higher points; tools and overalls left behind by workmen; bricks dropped through the manhole from the setting or from the boiler house itself;—these and many other miscellaneous things are found in our inspection work. Any of them may serve as centers for the collection of deposits which, by covering the heating surfaces, may bring on overheating and burning or bulging. The most serious deposits, in addition to the ones that have been considered in earlier sections, are those that consist mainly of cylinder oil, or of zinc oxide, or of organic matter that may have been introduced intentionally for the treatment of scale.

72. **CYLINDER OIL:** Lubricating oil should be scrupulously kept out of the boiler, because it forms a non-conducting coating over the fire sheets and tubes, and a film of this kind is apt to cause overheating, even though it is very thin. The oil usually gets into the boiler from the cylinder of the engine, by way of open

heaters in which the exhaust steam comes into direct contact with the feed water. When cylinder oil is found upon the inner surfaces of a boiler it may be removed by scraping, followed by scrubbing with a mop dipped in kerosene. This should be done when the boiler is cold, and in order to guard against explosion or fire, no artificial light should be used except an incandescent electric lamp; and even then the lamp should be protected by a substantial wire cage. In fact, all the precautions that are mentioned above, in paragraph 67, should be strictly observed. Oily deposits can be removed from the tubes of water-tube boilers by running a mop through them, saturated with kerosene. (See, also, paragraph 89.)

73. **ZINC SLUDGES:** Zinc is used more or less for preventing the pitting of boilers, and for the prevention of certain other forms of corrosion. It is most serviceable when the water is relatively free from scale-forming matter, and the plates and tubes are fairly clean. If there is free acid in the water in such cases, soda ash may be used with advantage for neutralizing it. When the water is quite pure and the corrosion is due to electrolysis or to the presence of dissolved oxygen, a pig of zinc is often suspended below the water level, and placed in good electrical connection with the shell or tubes of the boiler. Under these conditions the zinc is frequently attacked and dissolved, while

the boiler itself remains unaffected; but when zinc is so used a pan or other receptacle should be placed under it, to catch any fragments of metallic zinc or of zinc oxide that may fall off, and prevent them from lodging on the heating surfaces. Zinc oxide will often unite with fragments of scale, binding them together into a viscous sludge which later hardens into a tough, resistant, cement-like mass; and it will also combine with organic matter of certain kinds, to form an exceedingly hard, stony scale. Zinc is useful in connection with waters containing magnesia chloride,—which occurs abundantly in the ocean, and also to a considerable extent in deep wells. It is safest not to experiment with zinc in land boilers, however, unless a chemical analysis of the feed water has shown that its use is advisable.

74. **OTHER SLUDGES:** Graphite, when introduced for the prevention of scale (see paragraph 57), may form a sludge in the bottom of the boiler, if it is used to excess or if it is too coarsely ground. When used, it should be introduced in small quantities only. Potatoes, slippery elm, and various other kinds of organic matter, which are occasionally introduced into boilers for the treatment of scale, are quite apt to unite with the mineral matter present, and produce troublesome deposits. Organic substances of this nature should never be put into a boiler.

75. **HEAT LOSSES IN GENERAL:** Heat is wasted in many ways, in the operation of steam boilers, and it often happens that the significance of the waste is not appreciated either by the boiler owner or by his employees. Heat is an invisible, intangible thing, but its generation costs money, and the loss due to its waste is just as real and important as it would be if the escaping heat were composed of pennies or of dollars. It is well worth while, therefore, to consider every source of heat waste that can be discovered in the plant, and to consider what means should be taken to reduce the loss to the lowest practicable point. The commonest sources of heat waste about the boiler plant are mentioned below.

76. **FLUE TEMPERATURES:** The temperature of the gases in the uptake or smoke flue affords a useful indication of the economical performance of the boiler, although it sometimes requires skill and experience to interpret the temperature readings correctly. An unnecessarily *high* temperature in the flue usually indicates poor economy, because it shows that a considerable quantity of heat that should be absorbed by the boiler and utilized in the production of steam is being poured into the stack wastefully; but a *low* temperature does not always indicate good economy, because it may be due to leakage of air through the setting or through some of its connections, or to imperfect combustion in the furnace, accompanied by

extensive distillation of combustible gases in the unconsumed form.

At the moment of their emergence from the boiler, the flue gases must necessarily be somewhat hotter than the boiler or its contents, and in the best boiler-room practice the flue temperature is usually from 500° to 600° Fahr. When a materially higher value than 600° is observed, the conditions that lead to it should be investigated and remedied, because neglect to do so is likely to result in a large and probably continuous waste of heat. When the combustion is effected by means of an ordinary chimney or stack, a certain temperature in the escaping gases is essential to the realization of a proper draft. If the chimney and the other parts of the installation are correctly designed, the draft should be good with a flue temperature of 500° Fahr., as indicated above, unless the boilers are heavily overloaded; but good natural draft can rarely be had with a flue temperature materially lower than this. A high flue temperature may be due to any one of a number of causes. The boilers are perhaps being forced beyond their normal capacity, so that the flow of gas is too rapid to permit a proper absorption of the heat; or they may have become thickly coated with sediment and scale, internally, so that their heating surfaces are not in good contact with the water; or they may have become covered, externally, with a coating of non-conducting soot and dirt.

The thermometer that is used in taking flue temperatures should be of the highest grade. It should be bought of a dealer whose knowledge of instruments of this kind has given him an established reputation, and it should be tested from time to time, to detect any changes that it may undergo as the result of continued use.

77. **RADIATION:** The loss of heat by radiation from boilers and their settings, and from steam pipes, may be very serious indeed, unless care is taken to keep it down to as small an amount as possible. In some parts of the country it is common to see boilers standing out of doors, with no protection, even in winter, except the roof over them,—the sides of the boiler shed often being entirely open to the weather, with little or no provision for shielding the boilers and piping from the cold out-door air. This is exceedingly bad practice, not only on account of the waste of fuel that it entails, but also because the chilling action of the air upon the heated metal gives rise to severe strains that shorten the life of the boiler, and sometimes lead to immediate rupture. Stationary boilers should always be properly housed in and covered, and portable ones should be enclosed by suitable coverings that will protect them from direct exposure to the air. Pipes conveying steam should also be effectively covered with heat-insulating material, to reduce the radiation and con-

densation as much as practicable. The loss of heat from the brick-work of the settings is best prevented by care in designing the settings. There is less waste from this source when several boilers are arranged side by side with no spaces between their settings, than there is when the same boilers are set in single units, with passages between. It may be necessary to have such passages, to gain access to the rear of the boilers or for other reasons; but when this is not the case, it should be remembered that disposing the boilers in batteries is more economical so far as radiation is concerned, and that it also saves labor and material in erecting the settings. Water-tube boilers that require side cleaning doors cannot be set with more than two in a battery; and when a cleaning passage exists between boilers of this kind it should be at least five feet wide, so that the cleaning tools can be readily handled.

78. **COVERINGS FOR PIPES AND BOILERS:** The coverings that are used to check radiation from pipes and boilers should have good heat-insulating properties. Non-conducting coverings should be of such a nature that leaks from pipes or from the roof of the boiler house will not damage them seriously, and they should not be made of materials that are likely to char from heat. In selecting them, attention should be given, not only to the cost of the material, but also to its heat-insulating power, as determined by experiment.

Coverings upon pipes that convey steam or hot water under pressure should be applied in such a way that they can be removed readily for repairs or inspections,—particularly where the pipes enter fittings of any kind. In the event of a leak at these places, it will then be possible to examine the pipe and make the needed repairs at materially less expense than would be involved if the covering were put on without regard to this contingency.

79. **OPEN BOILER-ROOM DOORS:** In the summer season it is often necessary to keep the boiler room doors open, in order that the room may be comfortable for the attendants; but in the winter, especially in our northern latitudes, care should be taken to prevent the entrance of unnecessary quantities of cold air, because this increases the loss of heat by radiation from the boilers and piping. It must not be forgotten, however, that it is always necessary to admit to the boiler room a quantity of air sufficient to compensate for the air that enters the ash-pits and goes up the chimney or stack. The draft will be impaired if the doors and other openings into the boiler room are all kept tightly closed, because the pressure in the boiler room will then become reduced by the action of the chimney until the flow of air into the ash-pits may be checked to a notable extent. Air is sometimes drawn from the boiler room by fans, for warming other parts of the plant. This is poor practice, for several reasons. The air of the boiler

room is often charged with dust and ashes, and moreover as the fans act in direct opposition to the chimney, they are likely to check the draft very seriously unless the doors and other openings into the boiler room are left wide open.

80. **LEAKAGE AT THE BLOWOFF:** It often happens that the blowoff valve does not close tightly, either because it is worn or corroded, or because some obstacle has lodged on the seat. In such cases there is a continual flow of hot water out of the boiler, to an extent depending upon the magnitude of the leak; and the heat that escapes in this way is entirely wasted. Leakage of this sort is easily detected by the eye when the pipe discharges directly into the air. When it discharges into a sewer or a blowoff tank, however, some other method must be adopted. The simplest plan is to feel of the blowoff pipe from time to time. Leakage can be detected in this way very easily, because the continual escape of hot water, even in small amounts, keeps the pipe abnormally heated, beyond the valve.

81. **STEAM LEAKS:** The loss of heat due to the leakage of steam through a small opening is far greater than most persons are prepared to believe. It is easy to show, from accepted rules and tables for determining the flow of steam through orifices, that a hole one inch in diameter will discharge about 4,640

pounds of steam into the atmosphere per hour, if the pressure in the boiler is 100 pounds per square inch by the gage. Allowing 30 pounds of water per hour as the equivalent of one horsepower, it is plain that the steam that would pass away through this leak would be equivalent to more than 154 horsepower, so that it would require one good-sized boiler to merely supply the loss through this one hole. Smaller holes would be wasteful in proportion to their areas. A quarter-inch hole, for example, has an area equal to one sixteenth of that of the inch hole, and it would therefore waste an amount of steam equivalent to one-sixteenth of 154 horsepower, or to nearly 10 horsepower. It is evident from these figures that steam leaks about the boiler, or about its fittings and piping, are exceedingly important, and that great pains should be taken to stop them up promptly. A note should be made of leaks of all kinds, in order that they may not be overlooked when it becomes possible to repair them; but repairs should never be made upon any boiler or pipe while it is under pressure.

It should be remembered that steam leaks are sometimes hidden, and are to be found only by seeking for them. A familiar example of this kind is afforded when a stop-valve leaks between a steam main and a boiler that is temporarily out of use.

82. **LEAKAGE AT SAFETY-VALVES:** It is not at all uncommon for safety-valves to leak more or

less, whenever the pressure approaches the value at which they are set to blow off. This trouble is most common with the old-fashioned lever valves. It usually indicates a poorly fitting valve seat, though occasionally it may be that the seat would fit well enough if the disk could come down properly upon it, but that proper contact between the two is prevented by the lodgment of foreign matter either on the seat or somewhere else about the valve, or by the stem of the valve being bent, or by some other structural imperfection.

When the valve leaks, the cause should be ascertained and the proper remedy applied. It is often cheaper to throw away a leaky valve and replace it with a new one, than to run the old one and pay its coal bills.

The safety-valve should be tried at least once a day, to see that it blows freely. It is exceedingly unwise to economize steam by omitting this highly important precaution. The running pressure should not be near enough to the pressure at which the valve is set, however, to cause the valve to blow off frequently in the regular operation of the plant.

83. LEAKAGE AROUND VALVE STEMS: It is very common indeed to see steam blowing out around the stems of steam valves in a boiler room, or along the piping. This is usually quite inexcusable, because it can be easily remedied, ordinarily, by repacking the valve, or perhaps by merely giving the gland a turn or so with a wrench. It sometimes happens that the stem of a valve becomes bent, so that when the valve is opened or closed, the stem, by turning with a wobbling motion instead of remaining true, crowds the packing away from itself and so becomes almost impossible to keep tight. In cases of this kind the stem should be straightened or replaced.

84. **LEAKAGE AT PIPE JOINTS:** It is the exception rather than the rule, in a steam plant, to see no steam leaking from the joints of a pipe line. Leaks of this kind are often due to the use of improper gaskets. Old, hard gaskets are frequently employed when new ones would be far better, and far cheaper in the end. It is poor judgment to use an old gasket that will give rise to leakage, and thus waste a quantity of steam that costs many times as much as a new gasket. Leakage around steam pipes is a serious matter, not only on account of the loss of steam, but also because such leakage is often the visible evidence of a weakness of some kind, that may one day cause a bad accident. This is particularly true of leakage around threaded joints, because it is a common thing to make up such joints so that they do not fit properly, owing to the threads not being of standard form on the pipe or the fitting, or on both. Imperfect threads cannot be

"made up" properly. Hence when threaded joints leak, in large pipes conveying steam under considerable pressure, it is important to have the case considered by an inspector or other qualified man, to determine the cause of the trouble. It may be that a simple additional turn of the pipe or the fitting is needed, or it may be that the leak corresponds to a serious state of affairs that should be remedied at once by a more radical treatment. (Note, however, the warning in paragraphs 85 and 103, with regard to making repairs under pressure.)

85. **LEAKS IN GENERAL:** Wherever the leak occurs, it should always be borne in mind that it is exceedingly dangerous to make repairs of any kind upon a boiler or a steam pipe, or upon any fitting or other appliance or appurtenance, while it is subject to pressure. This maxim is frequently violated and *many men have paid the penalty of their lives in consequence.* (See paragraph 103.) A leak around the shell of a boiler, and particularly along a longitudinal riveted joint, calls for very special attention, as it may correspond to a lap-joint crack. Never calk such a leak, even with the pressure off, without taking advice from some person who is skilled in such matters. TRAVELERS' inspectors are at the service of our assured at all times, to give counsel upon any points that relate to the safety or economy of the boilers.

Oatmeal, potatoes, and many other substances, have been introduced into boilers to stop leakage at points below the water level. These substances act merely by plugging up the small openings through which the water escapes. They are objectionable for a number of reasons, and their use should be strongly discountenanced. (Compare paragraphs 58 and 74.)

86. **OTHER STEAM WASTES:** There are many other ways in which heat is lost about a steam plant through the waste of steam, and the engineer should always be looking for them, and he should remedy them at once when they are important enough to require attention. Steam jets discharging into the furnace of the boiler are sometimes used for improving combustion, and there is often no proper appreciation of the large amount of steam that is consumed in this way. Steam jets are also occasionally used for improving the draft, but except in locomotives, where it is impossible to provide the requisite draft by other means, this practice is too wasteful to be recommended. (See paragraph 25.) Steam jets are likewise employed for introducing gas, fuel-oil, and pulverized coal into boiler furnaces, and while the use of steam in this way is quite defensible, the apparatus should be under the control of some one who knows how easily large amounts of heat can be wasted by handling the jets improperly.

Tube cleaners that are operated by steam may be very wastefully used, and in applying these and other devices that consume steam, the fact that steam costs money should never be forgotten by the man in charge.

87. **HOT WATER:** Steam is often used for heating water, the steam being either blown directly into the water, or circulated through a coil of pipe submerged in it. The men often fail to realize that the capacity of water for heat is very great, and that a large amount of steam is required to raise the temperature of even a small tank of water through any considerable range. Hence they frequently draw off excessive quantities of steam in the wash rooms, and thereby waste heat. Wastefulness of the same general nature, though usually of smaller magnitude, may also occur when the water is heated in a special tank and delivered to the wash room through pipes; and when hot water is supplied in this way it is advisable to use a spring faucet, designed so as to close automatically when the man who is drawing the water releases his hold upon it.

88. **SAVING DRIPS:** A great deal of heat is lost by the improper disposal of the water of condensation that is formed in radiators, pipe coils, and other steam-using apparatus. Drips of this kind can easily be returned to tanks, from which they can be pumped

into the boilers and used as feed water. In some cases the drips are largely contaminated with oil, however, and when this is the case it may be better to throw them away, wholly or in part, rather than to take the chance of trouble from the introduction of the oil into the boiler. (See paragraph 72 for the effect of oil upon boilers, and paragraph 89 for suggestions regarding its removal from water.)

89. **FEED WATER HEATERS:** These are usually employed in connection with exhaust steam from the engines, and their primary purpose is to save as much as possible of the heat in the exhaust steam, by utilizing it to heat the feed water before pumping it into the boiler. They also serve to remove from the water a considerable amount of solid matter, which would otherwise be deposited in the boiler in the form of scale. This latter function, which may be very important when the water is bad and no external purifying device is provided, depends upon the fact that certain of the dissolved mineral substances are precipitated from solution when the temperature of the water is raised by a suitable amount. (See paragraph 45.) To increase the efficacy of the heater in this respect, a certain amount of live steam from the boiler is sometimes admitted to it.

Feed water heaters are of two general kinds, known respectively as the "open" and "closed" types. In the "open" heater the exhaust steam comes into direct contact with the water that is to be heated, and mingles with it upon condensing. In the "closed" type the steam does not come into actual contact with the water, but flows through coils of pipe submerged in it, or through equivalent passageways of some other kind, and warms the water indirectly, through the metal surfaces by which it is separated from the steam. In using open heaters special care must be taken to avoid introducing lubricating oil into the boilers. The oil comes over from the engines or pumps with the exhaust steam, and when it mingles with the feed water and is passed into the boilers, it is likely to give rise to a great deal of trouble. (See paragraph 72.) Many of the open heaters that are on the market therefore include devices for removing oil from the steam. When using an open heater of any other kind, an oil separator should be placed on the exhaust-steam line. Lubricating oil can be removed from water by filtration through a bed of straw, or through cloth, or by passing the mixture through a series of metallic plates perforated with small holes,—the oil adhering to the straw, cloth, or metal, and remaining behind.

Feed water heaters are often too small to be really effective. The same can be said of oil separators also. When selecting a heater or a separator great care should therefore be taken, to see that its capacity is adequate.

90. ECONOMIZERS: Economizers are used to a somewhat limited extent in the United States, but in Great Britain and other parts of Europe they are met with in nearly all of the larger power plants. An economizer consists of a series of strong, heavy tubes, placed in the flue between the boilers and the chimney, and used for heating feed water. The water passes through the tubes, and the waste gases from the furnace circulate around them. The feed water should enter the economizer at the cooler end, and leave it at the end that is nearest the boilers. To be effective, the economizer should be kept as clean as possible, both internally and externally. Mechanically-operated scrapers are provided for removing soot and other deposits from the exterior surfaces of the tubes, and caps or lids are located in the headers, opposite the ends of the tubes, to admit tools for removing deposits from the interior surfaces. The tubes gradually become coated, internally, with a peculiar black substance which appears to be a hydrate of iron, and in cleaning them this coating should not be disturbed. The scrapers for interior use should therefore be made of such a size that they will clean the tubes out to their original diameter, without removing any of the affected part of the metal. Thermometers should be provided to show the temperature of the water at the inlet and outlet of the economizer, and these should be tested from time to time to see that they register correctly.

All parts of the mechanism used for operating the external scrapers should be kept in first-class repair and in good adjustment.

Many of the accidents that occur to economizers are due to the leakage of gas through the dampers by which the economizers are separated from the boilers. Sometimes the danger consists in the accumulation of an explosive mixture of coal gas and air in the economizer chamber, and sometimes it arises from the leakage of hot gases around the tubes of an economizer that has been shut off from communication with the boilers, but left partly full of water. To guard against the accumulation of explosive gas mixtures in the chamber surrounding the economizer it is important to see that the damper *between the economizer and the boilers* closes tightly, and that there are ventilating doors in the setting of the economizer, to facilitate the circulation of air. The dampers usually become warped after being in service for a time, and they should therefore receive frequent attention. The ventilating doors in the setting should be opened as soon as the main damper in the flue is closed, and they should be left open during the entire period that the economizer is out of use. In small economizers it is usually sufficient to have one ventilating door, but in longer ones it is better and safer to have two or more such doors, according to the number of banks of tubes that are present. The damper between the economizer and the *chimney* should fit loosely, so that there may be enough leakage at this point to ensure the continuous entry of a certain amount of fresh air through the ventilating doors in the setting; and care should be taken to prevent the accumulation of soot around this damper, in such a way as to check the leakage through it. Some authorities recommend placing a ventilator in the damper that lies on the side nearest the chimney. To guard against the explosion of an economizer from the generation of a heavy pressure of steam within it, the water should be entirely drawn off immediately after closing the flue damper, and the blowoff valve at the bottom should be left open during the entire period that the economizer is idle. This valve should be secured in the open position, *and locked there*,—the engineer or superintendent having the key, and being held responsible for it. Every economizer should be provided with a safety-valve, and it is much better practice to provide two such valves. They should be kept in good condition and should be frequently inspected to see that they are working properly. Safety-valves that are used upon economizers are more likely to corrode than valves that are used on boilers, because in the economizer the valves are exposed to the action of water instead of to that of steam. Thoughtless boiler attendants often load them more heavily than the valves on the boilers with which they are connected, because when the economizer valves leak they allow water to escape, and external corrosion often results. This is a dangerous practice. To guard against the changing of the load on the economizer valves by any unauthorized person, they should be locked up so that no one can alter their setting without permission. It is advisable to drain the safety-valves, in order to prevent water from running down over the economizer in case of leakage. (See also paragraph 34.)

91. **SUPERHEATING:** In plants of large size, where a special study is made of every element that affects the economy, superheated steam is used quite extensively for the generation of power, both in reciprocating engines and in turbines. Superheated steam is merely ordinary steam that has been heated to a temperature higher than that of saturated steam having the same pressure; and the number of degrees by which its temperature exceeds that of the saturated steam is called its "degree of superheat". The superheating is performed in a device known as a "superheater", which, in its typical form, consists of a series of tubes through which the steam is passed, and which are exposed to a temperature materially higher than that of the contents of the boiler from which the steam is drawn. In their actual structure superheaters may vary to a considerable extent from the typical form here described. They are sometimes built so as to constitute an integral part of the boiler itself, and they are some-

times built separately, but located in the hot gases in the flues between the boilers and the chimney. Sometimes, too, they are entirely distinct structures, heated by separate furnaces.

The advantage of using superheated steam in the generation of power is due partly to the fact that the theoretical conditions upon which good efficiency depends are better satisfied when the entering steam is superheated, than they are when saturated steam of the same pressure is used. It is known, however, that superheating improves the theoretical cycle by only a small amount; and the improvement of the real cycle, which is usually much more pronounced when the superheating is correctly and effectively applied, appears to be largely due, in the reciprocating engine, to the lessening of the initial condensation that takes place in the cylinder when the steam enters it.

The power-generating apparatus of a plant that is to be operated by superheated steam should be designed as one single piece of apparatus,—the boiler, superheater, steam pipe, and engine being treated as parts of one organic whole, which must be well adapted to one another in order to ensure success. Many of the failures and disappointments that occur in the use of superheated steam are due to a lack of appreciation of this highly important fundamental principle. The steam pipe plays a particularly important part in superheated steam installations, but for some reason it receives but little attention in engineering books and periodicals. Radiation from the pipe should be kept down to the lowest point possible, because every unit of heat that is lost in this way diminishes the number of "degrees of superheat" of the steam, and thus tends to defeat the desired object, by cutting deeply into the economy that the superheating should bring. In bad cases the superheat may be entirely lost in the pipe, between the superheater and the engine. The radiative tendency is higher than it is with saturated steam of the same pressure, because the temperature of the superheated steam is higher. The pipe should be as short as practicable, it should be smaller in diameter than the piping that would be used for the same amount of saturated steam, and it should be effectively and heavily covered with a good non-conducting covering, not only around the body of the pipe itself, but also around its flanges and fittings. The temperature of the superheated steam being far higher than that of saturated steam of the same pressure, the motion of the pipe, as it expands and contracts under varying conditions of the service, will be correspondingly greater; and to provide against serious trouble from this source the piping should be designed so as to have proper elasticity. Its curves should be of large radius, and expansion loops should also be provided wherever necessary.

The temperature of superheat should be obtained by correct design and location of the superheater, and not by forcing the boiler. In making tests of newly-installed apparatus the constructors, if they do not obtain the desired temperature by other means, sometimes try to attain it by forcing the combustion under the boiler. This should not be done, because the superheater should be so proportioned and installed that the requisite superheat is obtained under the conditions that are to prevail in the regular, normal practice.

There are many special problems to be considered in connection with the use of superheated steam, and its adoption is not advisable except as the result of consultations with competent engineers who know what these difficulties are, and who are able to give intelligent opinions as to their magnitude and importance, and the best way of overcoming them. It is impossible to make any sound general statement as to the advantage or disadvantage of using superheated steam, nor can any intelligent general answer be given as to the best degree of superheating. In large installations that are designed with special reference to the use of superheated steam, a considerable degree of economy can be expected. If, on the other hand, the plant is small, and particularly if the duty of the engine is quite variable, and the personnel of the plant is not of a high order, the prospect of increase in economy is seldom great enough to warrant either the cost of the superheater, or the increased complication of the apparatus.

Copper should never be used for conveying superheated steam, because at high temperatures its strength and ductility are seriously reduced. There is, furthermore, a considerable difference of opinion among engineers as to the propriety of using cast-iron fittings in connection with superheated steam, as the behavior of superheated steam upon cast iron, when so used, is sometimes very marked, and of a nature that would hardly be foreseen by persons who have had no experience along these lines. Fittings made of it sometimes swell to a notable extent when exposed to superheated steam for a few months, and sometimes they change their shape by small amounts, or become filled with multitudes of cracks, so that their strength is destroyed. For these reasons steel is usually recommended in the place of cast iron. The steel should be carefully annealed, however, and the shape of the fittings has a great influence upon their durability.

The lubrication of the engine cylinder is a point of special difficulty in using superheated steam. It has occupied the attention of engineers from the time when superheating was first tried, and the difficulties that it has offered have been largely responsible for the slowness with which superheating has come into use. There is no difficulty involved in the lubrication of turbines, however, and for this reason superheated steam is almost invariably used in connection with turbine installations.

See, also, paragraph 34.

92. **FORCING BOILERS:** It is often necessary to run a boiler plant above its normal capacity, temporarily, in order to take care of special conditions that may arise, and the plant should be designed with this contingency in view. The efficiency of a boiler is greatest when the evaporative duty lies between certain limits which are determined by the size and design of the boiler and its accessories, and by the conditions under which it is used. Whenever a boiler is forced beyond this range of good efficiency, it becomes wasteful, and it also deteriorates with greater rapidity. If the work increases to such a point that it becomes necessary to force the boilers beyond their economical limit for any considerable part of the time, additional boilers should be installed at once.

In order to be able to regulate the load on the boilers as intelligently as possible, it is important to determine the duty, or rate of evaporation, at which the boilers of a given plant show their maximum efficiency when working under given conditions. Until this is known, the number of boilers that should be used when carrying a given load can be assigned only by a kind of educated guess-work; but when the duty at which the boilers yield the highest efficiency under given conditions has been determined, it is often possible to increase the economy of the plant by cutting out one or more boilers, or by putting additional ones into service, so as to approximate as nearly as possible to the duty at which each boiler gives the best results. The rating assigned to a boiler by its designer or builder is a nominal one, which is intended to represent, merely in a general way, the duty that can be expected from it under certain assumed conditions of operation; and the actual rate of evaporation at which the boiler is most economical, under the real conditions, can be accurately determined only by efficiency trials made at different loads. (See paragraph 101.)

93. **EXTRA BOILERS:** It is always advisable to install more boilers than are really essential for the economical operation of the plant in its usual state of activity. Several advantages are secured in this way. In the busier seasons, for example, the plant can be run without forcing the boilers improperly, and the boilers can also be cleaned more efficiently if one or two of them can be laid off without inconvenience. The installation of the extra boilers also dispenses, to a large extent, with the payment of extra wages for overtime work, which can seldom be avoided when all the boilers have to be used on every working day. Moreover, it is necessary to lay off one or more of the boilers from time to time, for inspection purposes, or for repairs; and when the plant has more boilers than are actually needed at any one time, this can be done quite readily, and without unduly forcing those that remain in service.

94. **LIGHT:** Boilers are frequently installed in dark and dismal places, and there appears to be a widespread belief, among designers and builders, that any place is good enough for a boiler room. This is a serious mistake, because the boilers and the engine are the heart and muscle of the whole plant, and their housing and maintenance should receive a corresponding share of attention. Good light is essential, if proper results are expected. If daylight cannot be had conveniently, a sufficient number of good, evenly distributed, properly shaded artificial lights should be provided. It is especially important to have the pressure gages and the water-glasses well lighted, so that there will never be any chance of error in reading the steam pressure or the water level. A reasonable expenditure for ensuring comfort and convenience in the boiler room is a wise investment, because the men will be more cheerful, and will do far more work, if the boiler room is comfortable, well lighted, and well ventilated; and the gain in this way is sufficient to make it decidedly profitable to attend to these points carefully.

95. **NEATNESS:** The importance of keeping the steam-gages, water-gages, and other indicating devices clean can hardly be over-estimated. In addition, the floor of the boiler room should be swept frequently, to prevent the accumulation of coal and ashes that fall from the handcars or barrows during

transportation; and when conditions permit, the floor should also be washed at suitable intervals with a hose. Debris should not be allowed to accumulate in dark corners; dust deposits should be cleaned periodically from the tops of the boilers and settings; and firing tools and other implements should be kept in good condition, and in their proper places. Windows and skylights should be kept clean, so that they may always admit as much daylight as possible, and electric lamps, lanterns, and other sources of artificial illumination should be kept in the best possible condition. The boiler-room walls should be brushed down at regular intervals, and a fresh coat of paint or of whitewash should be applied to them from time to time. Fittings of brass and nickel should preferably be kept polished. Everything that is needed for keeping the room in good condition should be liberally furnished, and a plentiful supply of water, soap, and towels should be provided, for the use of the firemen and other boiler-room attendants. The money represented by these various items is not wasted, for the men work better and more efficiently in a room that is properly kept; and if they are encouraged to attend to external appearances, they will extend the same thought and care to all parts of the work.

96. **SIMPLICITY:** Avoid all devices that are supposed to increase the efficiency of the plant in

mysterious ways. The generation of steam by the evaporation of water in a boiler is a simple process, so far as principles are concerned, and simplicity in the apparatus that is used for its practical realization is one of the first considerations to be sought for. Simplicity is not incompatible with efficiency, but tends to promote it if the management of the plant has a sound and correct basis. Avoid devices that are represented as operating on newly-discovered principles, or which appear to give something for nothing, or to effect a marvelous gain in economy. They may possibly be sound and effective, but the chances are a thousand to one against it. Practically all of them are in the experimental stage, and the vast majority are based upon entirely erroneous assumptions.

97. **UNIFORMITY OF PRACTICE:** It is conducive to economy to have the boiler-room practice as uniform as possible in all respects. The water level should be kept at a fixed point, except when it is temporarily lowered by opening the blowoff from time to time, as explained in paragraph 63. The steam pressure should also be maintained at a steady value, and an approved routine should be established for every detail in the room. When this is done the work will go on almost automatically, and in the best way possible. Any errors or omissions on the part of the attendants will also be more quickly observed.

98. **RECORDING GAGES:** We recommend the use of recording gages, where the plant is large enough to warrant the expense involved. The fact that a permanent record is being made leads to improvement in the boiler-room practice, and the men often take pride in maintaining a uniform pressure, when they know that success in this respect is sure to come to the attention of their superiors. Permanent records of all kinds are also useful in judging of the general performance of the plant, and in comparing the results that are obtained at different periods.

99. **METERS:** We advise the use of reliable water meters in connection with boiler plants, even though the water can be had without cost. They are particularly useful in estimating the evaporative performance of the boilers. The meters should be kept in good order, and their readings should be recorded at frequent and regular intervals by the engineer in charge, or by some other person definitely assigned to this task. (See paragraph 101.)

100. **WRITTEN RECORDS:** It is advisable to keep a boiler-room journal or log-book, in which all the events of the boiler house are entered as fully as practicable. As already suggested in earlier paragraphs, the record should include the amount of coal that is used and the quantity of water that is evaporated.

It should also cover supplies of all kinds that are added to the equipment, and everything that is consumed, discarded, or otherwise disposed of. It should also note every departure from the regular routine, and every unusual or occasional feature of the practice, such as the making of inspections, the discovery of defects, the recommendations for repairs, the dates when repairs are made and the nature of these repairs in full, and the failure of any accessories or appliances (such as the safety-valve, steam-gage, water-glass, or try-cocks) to work satisfactorily in any respect. The dates when the respective boilers are cleaned should also be entered, including a statement of the condition in which they are found; and full particulars should be given of what is done in opening them up, cleaning them, and restoring them to service again. In the same book a record may also be kept of overtime work, including the reasons for this work and the names of the men engaged upon it. The keeping of a log-book of this kind tends to increase the efficiency of the plant in much the same way as do the recording gages suggested in paragraph 98. Furthermore, the study of the record will often suggest ways in which economies can be effected without any sacrifice of efficiency. In a large plant it will of course be desirable to keep several books of this kind, each devoted to a special part of the work; but in a small plant a single record book will usually be sufficient for all purposes.

101. **EFFICIENCY TRIALS:** It is unwise to run a boiler plant year after year, with no attempt to ascertain the degree of efficiency that is obtained in it. Careful evaporative trials should be made from time to time to learn whether the service that is obtained is satisfactory or not. In every such test the quantities (such as the weight of the coal and the water, the temperature of the feed water, and the percentage of moisture in the steam and in the coal) that are essential to a definite knowledge of the evaporative efficiency, should be determined with special care. In the larger plants, tests of this kind are often carried out under the direction of experts retained for this purpose; but results of considerable value can also be had, after a little experience, by any competent engineer who will give thought to the subject.

The thermometers that are used in making boiler trials are often of a distinctly inferior character, and unsuitable for giving accurate results. Attention has already been directed to this point, in paragraph 76, in connection with the measurement of the high temperatures that occur in flues. Thermometers used in making important measurements at lower temperatures should be chosen with even greater care, because more accurate readings are required of them, and none but tested and guaranteed instruments should be employed. A great deal of otherwise good work is often worse than wasted by neglecting this caution.

When a boiler-room log-book is kept, as advised in paragraph 100, giving for each day the quantity of coal consumed and the amount of water evaporated, a very fair check can be kept upon the efficiency of the boiler plant as a whole, because the record makes it possible to find out roughly, at the end of each day's work, how much water the boilers are evaporating per pound of coal. Efficiency determinations of this kind are crude, because they do not take account of variations in the conditions under which the evaporation is performed; yet they give exceedingly valuable indications of the state of the plant as a whole. Moreover, their accuracy can be increased at will by enlarging the scope of the record and including feed water temperatures, tests of the wetness of the steam, and other items.

102. **DETERIORATION:** Attempts have been made to estimate the average life of a steam boiler, and to formulate rules by which the annual depreciation may be determined. Every attempt of this kind is foredoomed to failure, however, because the rapidity with which a boiler deteriorates cannot be expressed by any fixed rule. It necessarily depends in large measure upon the attendant conditions,—upon the quality of the feed water, the care that the boiler receives, and the duty required of it; and two boilers of the same age and construction, that are set

in the same battery and operated under similar conditions, may deteriorate at different rates. Deterioration is likely to be especially rapid in a boiler that is out of use, unless it is carefully laid up. (See paragraph 104.)

The evidences of deterioration are not always immediately apparent, and a coat of paint will sometimes make an old and unsafe boiler appear to be strong and sound, except to the most experienced eye. This shows, among other things, that it is a mistake to buy second-handed boilers unless they have been thoroughly investigated by a competent and trustworthy inspector.

103. **REPAIRS:** Repairs should always be made as soon as the need for them is discovered. Neglect in this respect usually leads to increased expense later on, because deterioration is likely to proceed rapidly when it has once made a good start. Delay may also impair the safety of the boiler. All recommendations that are made by the inspector should be carefully noted, and they should be carried out faithfully, whether they relate to the boiler itself, or to piping, fittings, or accessory apparatus of any other kind. The local engineer should never use his own judgment in this respect in preference to that of the inspector, because the inspector is part of a large body of experts having the operation of thousands of boilers under their eyes every day, and his counsel is

therefore based upon an experience far more comprehensive than that of the engineer in charge of the plant. Repairs should always be carefully and thoroughly executed, and makeshift methods should never be tolerated.

Repairs should never be made upon a boiler, pipe, or other vessel, while it is under pressure. (This holds true whether the repairs are trivial or serious.) Nuts should never be set up, nor pipes nor unions turned up, nor should a calking tool ever be touched to any part, until the pressure has been *entirely taken off*. It is exceedingly common to treat a small leak, while under steam, by a few blows with a calking tool or a punch, or to set up nuts, under like circumstances, on header caps or on the bolts of manhole covers or handhole plates. All this is highly unsafe practice, and it should be forbidden in every steam plant, with severe penalties for any infraction of the rule.

104. **LAYING UP BOILERS:** When a boiler is put out of service for a considerable time, it should be entirely emptied of water and every accessible part should be thoroughly cleaned, both inside and outside. The external surfaces should be scrupulously freed from soot, because after standing for a time the soot is likely to become damp by absorbing moisture from the air, and corrosion of the metal beneath is almost sure to follow. The tubes should be carefully cleaned,

and all deposits of dust and ash should be removed from the furnace and combustion chamber, and from the setting walls, both inside and outside. Scale and other deposits should be removed from the interior as completely as possible, and the boiler should be thoroughly washed out. Any water that remains standing in the bottom of the shell or elsewhere should then be removed with a mop or a sponge, or in some other way. Some engineers advocate burning papers or other light material in the furnace, to dry out the remaining moisture. We do not advise this, however, because there is always danger that the attendant will build too brisk a fire, and damage the boiler. The manhole and handhole plates should be left off, in any event, so that the air can circulate freely through all parts of the boiler. When this is done the interior will dry out without the application of heat, and the drying will proceed with special rapidity when the boiler is one of a battery, the other members of which are continued in operation. It is highly important to see that all the steam and water connections to the boiler are perfectly tight, so that no moisture can come in through them after the boiler is laid up. Boilers that are used only during certain parts of the year, and which lie idle during the intervening periods, should be cleaned and dried out with special care, each time they are laid off. The boilers of cotton gins, sugar houses, and greenhouses, are familiar examples.

As soon as the boiler has been laid up it should be carefully examined in all parts, to see if it needs repairs. Any that are found to be necessary should be made immediately, so that in case of emergency the boiler can be restored to service on short notice. This applies not only to the boiler itself, but also to all of its fittings and accessories.

105. **GOOD ENGINEERS AND FIREMEN:** It is hard to exaggerate the importance of having good men in charge of the boiler room. The unskilled man, who is willing to work for low wages, usually proves expensive. He is wasteful of fuel and of other supplies,—not intentionally, but because he is careless or unskilled. He commands inferior wages because he can give nothing but inferior service; and it is a serious mistake to put a man of this type at your coal pile with a shovel. There is also a large chance that the inferior man will damage the boilers and machinery under his care, by incompetence or neglect; and many costly boiler explosions have resulted from failure to do something or other in the right way, or at the right time. Sometimes the authority to hire the men, or to determine what shall be paid to them, rests with the wrong person,—with a person, namely, who does not appreciate that while a clerk can usually waste nothing but his own time, a boiler-room attendant can not only waste tons of coal in addition, but can also endanger the

whole plant. A mistake of this kind should be promptly rectified, by giving more authority to someone who has a better understanding of the boiler-room problem.

106. **INSPECTION AND INSURANCE:** Every boiler owner should insure his boilers with the best company he can find; and no other company is as well prepared as THE TRAVELERS, to render technical service of a useful, practical character. Its engineers and inspectors are men of wide mechanical experience, with a sound and thorough knowledge of boiler management; and you are cordially invited to submit to them any question or problem that may arise in your plant, bearing upon the safety or economy of your steam boilers. Inquiries should be addressed to THE TRAVELERS INDEMNITY COMPANY, Hartford, Connecticut.

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